Multistation Proprioceptive Exercise Program Prevents Ankle Injuries in Basketball

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ABSTRACT

EILS, E., R. SCHRÖTER, M. SCHRÖDER, J. GERSS, and D. ROSENBAUM. Multistation Proprioceptive Exercise Program Prevents Ankle Injuries in Basketball. Med. Sci. Sports Exerc., Vol. 42, No. 11, pp. 2098–2105, 2010. Purpose: To investigate the effectiveness of a multistation proprioceptive exercise program for the prevention of ankle injuries in basketball players using a prospective randomized controlled trial in combination with biomechanical tests of neuromuscular performance. Methods: A total of 232 players participated in the study and were randomly assigned to a training or control group following the CONSORT statement. The training group performed a multistation proprioceptive exercise program, and the control group continued with their normal workout routines. During one competitive basketball season, the number of ankle injuries was counted and related to the number of sports participation sessions using logistic regression. Additional biomechanical pre–post tests (angle reproduction and postural sway) were performed in both groups to investigate the effects on neuromuscular performance. Results: In the control group, 21 injuries occurred, whereas in the training group, 7 injuries occurred. The risk for sustaining an ankle injury was significantly reduced in the training group by approximately 35%. The corresponding number needed to treat was 7. Additional biomechanical tests revealed significant improvements in joint position sense and single-limb stance in the training group. Conclusions: The multistation proprioceptive exercise program effectively prevented ankle injuries in basketball players. Analysis of number needed to treat clearly showed the relatively low prevention effort that is necessary to avoid an ankle injury. Additional biomechanical tests confirmed the neuromuscular effect and confirmed a relationship between injury prevention and altered neuromuscular performance. With this knowledge, proprioceptive training may be optimized to specifically address the demands in various athletic activities. Key Words: PROPRIOCEPTIVE TRAINING, PROSPECTIVE RANDOMIZED CONTROLLED TRIAL, PREVENTION AND REHABILITATION, BIOMECHANICAL TESTS, NEUROMUSCULAR PERFORMANCE

Sporting activities such as basketball, soccer, team handball, and volleyball are high-risk activities especially for lateral ligament injuries of the ankle joint complex (8). In basketball, every other injury that occurs affects the ankle joint (21,27). These injuries often result in a considerable amount of time off for the injured players, typically 1 wk or more (16) or five to six sessions (18). Players may be unavailable for their team in important phases during the season, thus causing a serious problem particularly for professional or semiprofessional teams.

Different intervention methods have been recommended for the prevention of ankle injuries (17). There is evidence that ankle braces are effective in the prevention of acute, as well as recurrent, ankle sprains, but there is still controversy concerning the effectiveness of special training procedures (8). It was reported that proprioceptive training is not effective as a primary prevention in healthy subjects (4); however, recent results seem promising in underlining its effect as a secondary prevention in subjects with recurrent ankle injuries (3,11).

The effectiveness of specific training programs has been evaluated using prospective randomized controlled trials or laboratory-based studies (5–7,9,11,24,26). In prospective randomized intervention trials, a training group and a control group are monitored during a season, and differences in the number of injuries at the end of one season are indicative for the effectiveness of the training program. In laboratory-based studies, different test procedures are performed before and after a training period. Differences in neuromuscular performance are indicative of the effectiveness of the training program. However, both approaches are insufficient for a thorough understanding of ankle injury prevention. For example, when investigating the effectiveness of training programs, the reasons for possibly reduced injury rates might remain unclear. On the other hand, investigating the effects of a pre–post test design does not implicate that changes in neuromuscular parameters are
effective with respect to injury reduction. A combination of both approaches may help to improve our understanding of the relationship of ankle injury prevention and neuromuscular performance in athletes.

Therefore, the aim of the present investigation was to simultaneously evaluate the effectiveness of an intervention program for the prevention of ankle injuries as well as the effects of laboratory-based trials on neuromuscular performance during a basketball game season. The intervention trial was conducted as a prospective randomized controlled trial, with a laboratory-based aspect involving neuromuscular measurements in a subgroup before and after the training period. The underlying hypothesis was that there will be a significant reduction in the number of ankle sprains in the training group, and in addition, neuromuscular performance changes related to the specific multistation proprioceptive exercise program will be found in the training group.

METHODS

Subjects. The CONSORT statement was followed in the design of the study (1). The study contained a prospective randomized controlled trial and a pre–post laboratory-based test of a selected subgroup. The respective number of athletes recruited and investigated during the trial is shown in Figure 1.

In total, 232 players on 35 teams near Muenster, Germany, participated in the study (Table 1). All players played basketball on a regular basis, and the performance level of the players varied between the seventh highest
Before participation, all subjects signed an informed consent form. The tests were approved by the local human ethics committee, and all procedures were performed in accordance to the principles of the Declaration of Helsinki. Subjects were free of injuries at the start of the study. To evaluate the effect of the multistation proprioceptive exercise program on injury incidence, all subjects who wore external stabilizing devices (braces or tape) or who had previously performed proprioceptive exercises were excluded from the study. The remaining 198 subjects were randomly assigned to the control or the training group using a stratified randomization design, with the strata defined by performance (high, middle, or low) and sex (male or female).

TABLE 1. Anthropometric data of the whole (upper part) and the biomechanical subgroup (lower part).

<table>
<thead>
<tr>
<th></th>
<th>Training Group (n = 81)</th>
<th>Control Group (n = 91)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>22.6 ± 6.3</td>
<td>25.5 ± 7.2</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>77.2 ± 15.3</td>
<td>77.8 ± 14.6</td>
<td>NS</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>184.1 ± 11.0</td>
<td>183.6 ± 10.4</td>
<td>NS</td>
</tr>
<tr>
<td>Sex, M/F</td>
<td>49:32</td>
<td>54:37</td>
<td></td>
</tr>
<tr>
<td>Sports activity (per week)</td>
<td>3.5 ± 1.1</td>
<td>2.8 ± 0.9</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Previous injuries (%), Y/N</td>
<td>48.52</td>
<td>46.54</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Training Group (n = 8)</th>
<th>Control Group (n = 8)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>24.3 ± 2.9</td>
<td>25.9 ± 8.2</td>
<td>NS</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>75.8 ± 12.4</td>
<td>80.6 ± 18.6</td>
<td>NS</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>182.1 ± 6.9</td>
<td>184.4 ± 7.8</td>
<td>NS</td>
</tr>
<tr>
<td>Sex, M/F</td>
<td>4:4</td>
<td>4:4</td>
<td></td>
</tr>
<tr>
<td>Sports activity (per week)</td>
<td>2.0 ± 0.4</td>
<td>3.5 ± 1.8</td>
<td>NS</td>
</tr>
<tr>
<td>Previous injuries (%), Y/N</td>
<td>63.37</td>
<td>75.25</td>
<td></td>
</tr>
</tbody>
</table>

Differences between groups (training and control) were tested using the independent Student's *t*-test (whole group) and the independent Mann–Whitney *U*-test (biomechanical subgroup).

NS, not significant.

Exercise 1
Basic Exercise: Walking slowly back and forth on a balance beam (1 step=3 seconds). The contralateral leg swings through and nearly touches the ground.

Variation 1: Walking faster than before on the balance beam. Way back: slowly with same execution as above.

Variation 2: Stance on a balance beam. The contralateral leg moves a basketball that lies on the ground in circles. Focus on the supporting leg.

Exercise 2
Basic Exercise: Single leg stance on exercise mat with the contralateral leg flexed. Lower and raise the body. Distribute load on the foot. Only small knee movements to the left and right are allowed.

Variation 1: Single limb stance as above opposite to a partner. A basketball is passed to the partner. After catching the ball, the position is controlled for 2 seconds. Pass the ball back and forth.

Variation 2: Single leg stance on a soft mat. Balance a ball (tennis ball, basketball) on the dorsum of the elevated contralateral foot.

Exercise 3
Basic Exercise: Jump from one leg to the other on an exercise mat and control landing for 4 seconds. Raise the contralateral leg.

Variation 1: Jump from one leg to the other (exercise mat) with a partner. Disturb each other during the flight phase (hand contact) and control the landing and stance for 4 seconds.

Variation 2: As before, but on a soft mat.

Exercise 4
Basic Exercise: Walk up and down an inclined surface and dribble the ball.

Variation 1: Walk on inclined surface up and down and dribble the ball. In addition, an elastic strap is wrapped around the knees. Walk forwards and backwards. Focus on wide steps.

Variation 2: Walk and down an inclined surface. An opposite partner is doing the same. Pass the ball between partners and move up and down with only the forefoot in ground contact.

Exercise 5
Basic Exercise: Maintain balance in single-leg stance.

Variation 1: Maintain balance in single-leg stance (eyes closed) elevating the contralateral leg against resistance of an elastic strap.

Variation 2: Maintain balance in single-leg stance moving the contralateral leg sideways against resistance of an elastic strap.

Exercise 6
Basic Exercise: Maintain balance in single-leg stance on inversion-eversion tilt board. The contralateral leg is rested on an inclined surface nearly without being loaded.

Variation 1: The same as above with a partner. Pass the ball and control stance after catching the ball.

Variation 2: Maintain balance in single-leg stance on inversion-eversion board. The contralateral leg is elevated.

FIGURE 2—Exercises and variations of the multistation proprioceptive exercise program. Please note that this is only a short description of the program and the exercises.
female). It has to be noted that subjects were allocated to the groups as teams because the balanced training program had to be integrated in the normal training process. Teams were assigned using random numbers (0 and 1) that were generated by a computer program. The randomization list was established in advance and was strictly maintained. This finally resulted in two randomized groups that were comparable in performance and sex.

Training program. The control group consisted of 102 players who continued with their normal workout routines. The training group consisted of 96 players who performed a multistation proprioceptive exercise program that was designed in cooperation with the School of Physiotherapy of the University Hospital Muenster. The program was integrated within the regular training routines and was especially designed for basketball workouts. At the beginning of the season, each coach obtained an eight-page training manual that contained a detailed description of the setup, all exercises (including the different difficulty levels), and additional background information concerning posture corrections and proprioception. In addition, a physiotherapist introduced this program to all players and coaches on site and gave detailed instructions for correct execution. This was repeated for each difficulty level. During the season, the coaches were encouraged to contact us and were contacted by us on a regular basis to keep them motivated and to help with questions or problems.

The multistation program was adopted from a program presented by Eils and Rosenbaum (5). It was performed once a week and consisted of six stations that were performed twice (barefoot) at the beginning of the normal training routine (Fig. 2). The exercise period took 20 min (including setup and removal). The exercises were performed for 45 s followed by a 30-s break when subjects transferred to the next station. The correct posture of the subject’s lower leg was controlled (slight external rotation of the foot, slightly flexed knee and the patella over the metatarsophalangeal joint) during the exercise. The intensity and difficulty of the exercises were increased during the season twice by minor modifications for each station.

Injuries. From the beginning of the season, all injuries of the players in a team were registered by a person in charge of the team (coach, physiotherapist, or player) using a specific injury questionnaire that was filled out and returned in case of an injury. To reduce reporter’s bias to an acceptable degree, we contacted the coach and the player to obtain further information about the circumstances, the severity, and the medical diagnosis. All injuries were reported, but the contact to the coaches and players was only arranged in case of ankle injuries. An injury was defined as an event that forced the subject to terminate the ongoing basketball activity and, in addition, prevented further participation in the next scheduled basketball activity.

Biomechanical tests. Additional biomechanical tests were performed in a subgroup of both the control and the training groups to investigate the influence of the training program on neuromuscular performance. The subgroup was randomly selected using a stratified randomization design as mentioned previously. Subsequently, players within these teams were randomly selected and asked for participation in the study. Finally, 24 subjects (11 in the control group and 13 in the training group) were enrolled and performed the pretests in angle reproduction and postural sway. During the season, eight players of this group (three from the control group and five from the training group) were lost because of different reasons (Fig. 1). Finally, data of 16 players (eight from each group) who performed both pretest and posttest could be analyzed.

A pressure distribution platform (Emed ST4; Novel GmbH, Munich, Germany) was used to measure postural sway in single-limb stance (Fig. 3). No instructions concerning the posture were given to the subjects except to avoid contact of the legs and to focus on a point on the wall directly ahead. Individual posture was noted, and subjects were informed to...
use the same style as in the pretest when it deviated in the posttest. For each foot, three trials of single-limb stance (10 s each) were performed. For analysis, the sway variation and the sway amplitude of the center of pressure (CoP) in mediolateral and anteroposterior directions as well as the total sway distance (total length of the CoP-line) were determined and averaged.

A custom-built device was used for testing joint position sense in a passive angle reproduction test. It consisted of a footplate in combination with a Penny and Gilles goniometer (Biometrics Ltd., Gwent, UK). Subjects sat in front of the measuring device and placed the foot on the horizontal footplate (Fig. 4). The rotation axis of the device 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 test, the foot was brought into one of the two testing positions (10° dorsiflexion or 15° plantarflexion) and was held for 2 s. Then it was brought back to the neutral position and back toward the testing position until the subjects indicated that they felt they had reached the same position. The foot was returned to the neutral position, and the next angle was chosen. Angles were tested in random order, and each angle was tested three times. All joint position tests were performed by the same investigator. The differences between predefined and reproduced angles were saved for analysis. Lower leg strength was not tested in this study because it was shown that deficits in ankle strength are not related to chronic ankle instability or subjects who previously sustained sprains without instability as a complaint (12,19,28).

**Statistics.** To calculate the injury incidence of the groups, the number of injuries was related to the number of sports participation sessions (game and practice sessions combined). Data were then analyzed by logistic regression. The results were presented as odds ratios of injury as well as the numbers needed to treat (NNT). Pre–post test analysis was performed using the dependent nonparametric Wilcoxon signed-rank test. Differences between groups (training and control) were tested using the independent Student’s *t*-test (whole group) and the independent Mann–Whitney *U* test (biomechanical subgroup). Prediction intervals on the basis of the data of the total study population were used to test the representativeness of the biomechanical subgroup. In all statistical procedures, *P* < 0.05 was regarded as significant. Statistical analyses were performed using SPSS v.17 (SPSS, Inc., Chicago, IL).

**RESULTS**

During the season, 21 ankle injuries occurred in the control group and 7 injuries in the training group. Significant differences were found when focusing on the preventive effect of the multistation proprioceptive exercise program (Table 2). The logistic regression revealed a significantly reduced odds ratio of 0.355 for training versus control group (95% CI = 0.151–0.835, *P* = 0.018). The NNT analysis revealed a value of 360 for the training group. Because the observation unit is not the player but the single participation in sports, the NNT values have to be reconsidered. Therefore, with a mean of 55 sports participation sessions in our investigation (mean of both groups), NNT values have to be corrected to 360/55 = 6.5. This indicates that seven basketball players (NNT values are rounded to the next number to avoid underestimation) have to perform the multistation proprioceptive exercise program to prevent one ankle injury during 55 sports participation sessions, i.e., in a period of 18 wk for recreational players (assuming two workouts per week, one game per week) or 9 wk for professional players (assuming five workouts per week, one game per week).

Analysis of players who had previously sustained an ankle injury revealed an odds ratio of 1.6 (95% CI = 0.755–3.553, *P* = 0.212), indicating an increased but nonsignificant risk (factor = 1.6) of sustaining an ankle injury.

Players of the training group showed a significantly more stable single-limb stance concerning mediolateral and overall

| TABLE 2. Number of ankle injuries, participation in sports, injury frequency related to 1000 participations in sports, odds ratios, and NNT. |
|-----------------|-----------------|-----------------|
| | Training Group | Control Group |
| Absolute No. of injuries | 7 | 21 |
| Total No. of participations in sports | 4565 | 4876 |
| Injury frequency per 1000 sport participations | 1.53 | 4.31 |
| Odds ratio (95% CI), *P* | 0.355 (0.151–0.835), 0.018 | 1 |
| NNT | 7 | — |
sway parameters (Table 3). Sway in the anteroposterior direction was also decreased in the posttest, but this was found not to be significant. Players in the control group also showed slightly decreased values in the posttest, but none of the differences was significant.

A clear effect of the training program is apparent for the angle reproduction test. The degree of error for 10° dorsiflexion and 15° plantarflexion and the mean were significantly reduced for the posttest in the training group but not in the control group (Table 4).

**DISCUSSION**

The present investigation evaluated the effectiveness of a multistation proprioceptive exercise program for the prevention of ankle injuries using a prospective randomized controlled trial in combination with a laboratory-based pre–post test. The results suggest that the training program is effective in reducing the incidence of ankle injuries in basketball players and also leads to specific changes in neuromuscular performance, specifically, in proprioception and postural sway. In summary, these findings indicate that improvements in these neuromuscular parameters may be a key factor for an effective reduction in ankle injury risk.

The multistation proprioceptive exercise program led to a significant reduction of ankle injuries in basketball players. The risk of sustaining an ankle injury was reduced by 35.5%, and the NNT analysis revealed that seven players have to be treated with this training program to prevent one ankle injury during 55 sports participation sessions. This underlines the potential benefit of an active injury prevention protocol, especially in professional sport. Results for risk reduction and NNT calculation are comparable to results in the literature. For example, Hupperets et al. (11) recently reported a similar NNT value of 9 and a relative risk reduction of 35% in the training group but not in the control group. However, it remains unclear whether the measured effects of this “low-frequency and high-stimuli” program would lead to a reduction in the number of ankle injuries. The results of the present study underlined the effectiveness of such a program and suggested that training-induced changes within the neuromuscular system may be related to the reduced incidence of ankle injuries. It must be noted that a direct one-to-one relationship cannot be established because only a subgroup of the entire cohort was evaluated in the laboratory because of organizational concerns. However, although the sample was small, it was randomly drawn and was representative. A post hoc analysis using prediction intervals on the basis of data of the total study population revealed that the sample is proven to be representative of the total study population except for the rate of high-performance players. Furthermore, significant differences were found between pretest and posttest. The study design involving a randomized controlled trial combined with laboratory-based testing is important in more appropriately identifying the relationship between ankle injury prevention and neuromuscular performance compared with independent randomized controlled trials and laboratory-based testing. This relationship will help to understand better the complex interaction between injury prevention and neuromuscular performance.

Recently, the importance and efficacy of complex intervention programs consisting of a variety of exercises have

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**TABLE 3. Postural sway parameters (mean ± SD).**

<table>
<thead>
<tr>
<th>Postural Sway (mm)</th>
<th>Training Group</th>
<th></th>
<th>Control Group</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pretest</td>
<td>Posttest</td>
<td>P</td>
<td>Pretest</td>
</tr>
<tr>
<td>SD mediolateral</td>
<td>5.8 ± 0.7</td>
<td>5.1 ± 0.8</td>
<td>&lt;0.05</td>
<td>5.4 ± 1.3</td>
</tr>
<tr>
<td>SD anteroposterior</td>
<td>6.7 ± 0.9</td>
<td>6.8 ± 1.3</td>
<td>NS</td>
<td>7.4 ± 1.8</td>
</tr>
<tr>
<td>Maximum sway mediolateral</td>
<td>26.9 ± 3.9</td>
<td>23.1 ± 3.5</td>
<td>&lt;0.01</td>
<td>25.3 ± 4.9</td>
</tr>
<tr>
<td>Maximum sway anteroposterior</td>
<td>33.1 ± 4.5</td>
<td>28.9 ± 3.9</td>
<td>NS</td>
<td>34.1 ± 8.7</td>
</tr>
<tr>
<td>Total sway distance</td>
<td>425.2 ± 47.5</td>
<td>359.2 ± 57.7</td>
<td>&lt;0.05</td>
<td>351.2 ± 73.8</td>
</tr>
</tbody>
</table>

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**TABLE 4. Angular errors in the joint position test from predetermined angles (mean ± SD).**

<table>
<thead>
<tr>
<th>Degrees of Error (°)</th>
<th>Training Group</th>
<th></th>
<th>Control Group</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pretest</td>
<td>Posttest</td>
<td>P</td>
<td>Pretest</td>
</tr>
<tr>
<td>10° dorsiflexion</td>
<td>2.0 ± 0.5</td>
<td>1.2 ± 0.5</td>
<td>&lt;0.05</td>
<td>2.5 ± 1.3</td>
</tr>
<tr>
<td>15° plantarflexion</td>
<td>3.7 ± 1.4</td>
<td>2.1 ± 1.2</td>
<td>&lt;0.05</td>
<td>2.3 ± 0.8</td>
</tr>
<tr>
<td>Mean error</td>
<td>2.9 ± 0.6</td>
<td>1.7 ± 0.6</td>
<td>&lt;0.05</td>
<td>2.4 ± 0.8</td>
</tr>
</tbody>
</table>

Neuromuscular training programs consisting mainly of exercises on an ankle disk, performed several times per week, were found to be effective in the reduction of ankle injury incidence (6,9,20,23), although Handoll et al. (8) questioned the efficacy in an evidence-based review of the literature because of a limited amount of high-quality studies. Preliminary evidence was given only for those with previous ankle injuries. Eils and Rosenbaum (5) speculated that specific training on an ankle disk probably generated only single stimulation and, therefore, introduced a 6-wk multistation proprioceptive exercise program that addressed strength and coordination in multiple ways and was performed only once a week. The authors showed that this program led to significant improvements within the neuromuscular system in the training group but not in the control group. However, it remains unclear whether the measured effects of this “low-frequency and high-stimuli” program would lead to a reduction in the number of ankle injuries. The results of the present study underlined the effectiveness of such a program and suggested that training-induced changes within the neuromuscular system may be related to the reduced incidence of ankle injuries. It must be noted that a direct one-to-one relationship cannot be established because only a subgroup of the entire cohort was evaluated in the laboratory because of organizational concerns. However, although the sample was small, it was randomly drawn and was representative. A post hoc analysis using prediction intervals on the basis of data of the total study population revealed that the sample is proven to be representative of the total study population except for the rate of high-performance players. Furthermore, significant differences were found between pretest and posttest. The study design involving a randomized controlled trial combined with laboratory-based testing is important in more appropriately identifying the relationship between ankle injury prevention and neuromuscular performance compared with independent randomized controlled trials and laboratory-based testing. This relationship will help to understand better the complex interaction between injury prevention and neuromuscular performance.

Recently, the importance and efficacy of complex intervention programs consisting of a variety of exercises have
also been reported for volleyball players (26) and in athletes with acute ankle sprains (10,11). Therefore, there is new evidence that proprioceptive training programs with challenging exercises to create multiple stimuli may be recommended for the prevention of ankle injuries. The effects of proprioceptive training have been well documented in the past, and laboratory-based studies concerning alterations in joint position sense, sway regulation in single-limb stance, muscle strength, or peroneal reaction times have been performed (5–7,9,12–15,24,25). Despite differing findings (22), there seems to be a trend of characteristic neuromuscular performance adaptations because of specific training programs.

In the present investigation, the results of the angle reproduction test show a significant improvement in neuromuscular performance. The results of the sway regulation are similar, but not all improvements in the training group were significant. The training program seems to be more effective in improving sway reduction in the mediolateral direction. This is comprehensible because movement in the mediolateral direction is mainly controlled in the subtalar joint, whereas the movement in the anteroposterior direction is more regulated in the tibiotalar joint. A similar result was reported by Eils and Rosenbaum (5) when evaluating the effects of a multistation proprioceptive exercise program in patients with ankle instability.

In previous studies, the relationship between training-related changes within the neuromuscular system and the effectiveness of injury prevention was vague. In the present investigation, this relationship was evaluated for the first time with parallel biomechanical testing in a smaller subgroup, including angle reproduction and postural sway testing. Although we analyzed only a small subgroup and we are aware of the fact that other factors may play a role in this context, we believe that the results of the present study underline a more direct relationship between measured alterations within the neuromuscular system and the effectiveness of injury prevention than shown in previous studies because the sample was randomly selected and representative. Results of the postural sway analysis in single-limb stance and angle reproduction showed significant differences within the training group but not in the control group for selected parameters. Therefore, an improved ability to detect a predetermined angle (improved joint position sense) and the ability to regulate sway in single-limb stance seem to be related to a reduction of lateral ankle injuries. These improvements may help athletes to prevent ankle injuries in potentially dangerous circumstances, e.g., in cutting and landing movements, because of an improved joint position sense of the foot and ankle complex.

At this point, it will be of interest how exercises have to be designed to be most effective. For example, what are the effects of a typical ankle disk training compared with a more complex exercise on a neurophysiologic basis? Is it possible to derive some typical characteristics or “key aspects” that make an exercise more suitable for proprioceptive training? However, this remains speculative and has to be addressed in additional biomechanical studies.

One aspect that needs clarification in the present investigation is the influence of proprioceptive training on subjects with and without previous ankle injuries. It has been stated that a beneficial effect is most pronounced for athletes with previous ankle injuries and that there is only a small or no effect of training in healthy subjects (4,8). We found an increased chance (factor = 1.6) of obtaining an ankle injury in subjects with previous injuries. However, this increase was not significant. Only players who never performed proprioceptive exercises or wore ankle-stabilizing devices before were included in the present investigation. Therefore, a high percentage of players with previously injured ankles have probably been excluded, resulting in a similar percentage of players (approximately 50% each) with and without previous injuries. This explains why the effect for players with previous injuries is not as pronounced as that in other investigations (2,16,26).

Significant differences between players’ age and sports activity were initially found between the training and control groups. The players in the training group were significantly younger (22.6 vs 25.5 yr) and more active (3.5 vs 2.8 times per week) than the controls. These group differences actually emphasize the findings because it can be argued that younger and more active individuals would have a greater risk of injury because of increased exposure.

The results of the present investigation show that the number of ankle injuries was reduced, but there was no information concerning other injuries. This might be a limitation in the present study because it would be of interest to know whether ankle injuries may be replaced by injuries in other areas. We were not able to derive this information from our data because coaches and players were contacted only in case of ankle injuries. However, a systematic Cochrane review focusing on interventions for preventing ankle ligament injuries did not report an apparent effect on the incidence of other leg injuries (8). This leads us to trust that there is no significant shift of injuries to other body areas.

**CONCLUSIONS**

The results of the present investigation show that a specific multistation proprioceptive exercise program performed only once a week significantly reduced the frequency of ankle injuries in a population of basketball players. In addition, characteristic and significant improvements in neuromuscular performance were found in biomechanical tests of proprioception and postural sway that may be directly related to the risk of ankle injury. This is the first study to underline directly a relationship between injury incidence and alterations in neuromuscular performance. The evaluation of injury incidence as well as
objective parameters from biomechanical tests warrants the recommendation of such exercises for the prevention of ankle injuries.

Although the population were basketball players, it may be safe to assume that the program is also applicable to other sports or high-risk activities such as team handball, volleyball, or soccer.

REFERENCES


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The results of the present study do not constitute endorsement by the American College of Sports Medicine.