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Intervention Study

Muscle Function among Healthy Adult Athletes before and After a Postural Balance Training Period

Annika Larsson[1*] MSc, RPT, Börje Rehn[2] Associate Professor, RPT, Sven Blomqvist[3] PhD, RPT

[1]*Umeå University, Sweden*

[2]*Department of Community Medicine and Rehabilitation, Physiotherapy, Umeå University, Sweden*

[3]*Faculty of Health and Occupational Studies, University of Gävle, Sweden*

**Corresponding author: Annika Larsson, Umea University, Sweden,Tel: +46737633715;*

Email: annika.maria.larsson@gmail.com

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Abstract

Background: Postural balance training is primarily used by athletes as rehabilitation after previous injuries or for prevention. A few studies have been made with the aim of investigating whether postural balance training can improve other physical functions in healthy participants. However, there is no consensus regarding effects.

Objective: The aim of this study was to investigate whether postural balance training can improve muscle function in healthy adult athletes.

Method: Seventeen healthy adult (6 males and 11 females) athletes between the ages of 21 and 50 years performed three postural balance exercises once a day 3x30 seconds per exercise on each leg. This intervention was performed daily for six weeks. Their muscle function were assessed with squat jump, heel rise and grip strength (control). Evaluation was done before and after the training period.

Results: Jump height, number of repetitions in heel rise and duration in standing on one leg increased with statistical significance. There were no improvements in postural sway and grip strength.

Conclusion: The results suggest that a postural balance training period can provide a better local muscle function regarding explosive strength and endurance among adult athletes even if postural sway is not affected.

Keywords: Muscle strength; Equilibrium; Exercise; Physical examination

Background

Postural Balance Training (PBT) can be used as a rehabilitation training method for athletes after injury. The theory behind PBT is that the athletes' bodies will become more stable and thereby better able to withstand impacts from external forces, which would otherwise increase the risk of reinjuries. Although the advantages of PBT are generally accepted, and it is seen as a training method to prevent and rehabilitate injuries [1], some training regimes for athletes does not include PBT. Athletes and trainers might be more motivated if it could be shown that the effects of PBT also improve muscle function to the advantage of their own sports.

Balance ability develops from childhood to adulthood and then reduces with increased age [2,3]. Older individuals have reduced strength and balance due to the naturally degenerative process [2-4]. This is especially due to a delayed anticipatory postural adjustment compared to younger individuals.

However, the ability to recruit muscles may be intact [5]. By being physically active, mainly with sport/tasks that challenge the postural system, it can lead to a retained balance even in older age [6]. Studies have shown that strength training for elderly people improves the balance ability [7] and decreases the risk of falling [4].

During ordinary physical training there is an increase in strength which has been described to occur in two stages, but with overlap. In the first stage a process of neural adaptation occurs which facilitates a more efficient recruitment of muscle fibers [1]. The second stage involves muscle fiber growth by increasing their cross-sectional area [8]. Hypertrophy occurs in all fibers, however the fast twitch fibers has an 50% higher growth-capacity than slow twitch fibers [9]. Especially the neural component involved in gaining strength may be trained by PBT.

The impact of PBT on physical performance in healthy individuals has been investigated in few studies in a variety of groups and results. Granacher and Gollhofer [10] did not find any association between balance and strength among non-active adolescents. Granacher et al [11] showed that active adolescents increased their jump height after a period of PBT. Gruber and Gollhofer [12] also reported an association between PBT and an increased jump height. Kean et al [13] demonstrated that PBT improved jump height in healthy, female adult volley-ball players. Thus, there is no consensus from studies made so far and more research is necessary to discover effects also among other groups.

Aim

The aim of this study was to investigate if postural balance training can improve strength, endurance, balance and grip strength in healthy adult athletes.

Method

This was an experimental study with measurements before and after a PBT intervention. The inclusion criteria were; healthy adults between the ages of 18-50, active in sports at least three times/week for an on-going period of at least two years in conjunction to the intervention. Individuals being actively treated due to injury/pain in the lower extremities or lower back or with a history of injury within the past year were excluded. Individuals were prohibited from initiating any new training routine during the study.

Sample

Participants were chosen by self-selection. Information about the study was spread via posters in three nearby martial arts gyms, two gyms, two floor ball teams (one male and one female), all in Uppsala city-in Sweden- as well as in the Uppsala University´s department for physiotherapy. Information was also spread via e-mail to all physiotherapists working in the primary healthcare in Uppsala and to a middle school just outside Uppsala where many employees are physically active. The selection process took place from November of 2012 to February of 2013. Those who considered themselves suitable for the study were instructed to make contact via e-mail or telephone, at which point the study leader (AL) confirmed whether or not they met the inclusion criteria.

At the pre-intervention test session, the participants drew a number from a sealed envelope and were thereby coded. The same physiotherapist (AL) performed tests before and after the intervention. The results from the test session were hidden until the post-intervention tests were complete.

Equipment and evaluation instruments

Muscle function was evaluated using a variety of functional tests. Squat jump (SJ) [14] was used to test explosive strength in the lower extremities and performed on a force platform. Heel rise [15,16] was used to measure endurance. Standing on one leg with eyes closed (SOLEC) [17,18] was used to assess both postural balance and endurance and was performed on a force platform. Grip strength was used to measure if there was a more general increase in strength away from the lower extremities [15], caused by an increased central drive and used as a control. Heel rise and SOLEC were tested on the dominant leg, which was chosen by the question "which foot do you kick a ball with". Grip strength was tested with the dominant hand, the one that the participants used for writing.

Squat jump

Squat jump (SJ) is considered to have a good validity and reliability for adult, physically active men and was used in this study to assess vertical jump height [14,15]. SJ was performed on a force platform (Muscle Lab ET-FP-01) where jump height in centimetres was used as the outcome measure and measured by the time the participant was in the air, correlated to height and weight. The result was analysed with Muscle Lab model 400E and the software MuscleLab 8.0 (Ergopower Technology (Porsgrunn Norway)). Participants stood with their hands on their hips, bent their knees to approximately 90 degrees and remained in that position for a couple of seconds. They were then told to jump straight up in the air as high as possible without using their arms as assistance. The time participants waited in this position was determined by the platform, which sensed when the subject stood completely still. When the platform signalled that the participant was perfectly still, the test leader told the participant to jump. Each participant was allowed a trial jump in order to become accustomed to the correct jump technique. The best of three vertical jumps was used for evaluation [14].

Heel Rise

Heel rise has shown a good validity and reliability tested on young, healthy men [15,16].

In heel rise, participants stood on their dominant leg and were allowed to use the wall to maintain balance. The participants performed one-legged heel rises with a pace set by a metronome with 40 bpm. They performed as many heel rises as possible using a plate marked with a line set at 5 centimetres above the navicular bone, which was attached to the wall as a guide. The test ended when a participant was unable to keep up the set pace, did not maintain heel rise elevation as indicated by the plate, or ceased on their own volition due to experienced difficulty. Three inaccurate heel rises were permitted with the fourth as the indicator that testing should be halted. The maximum number of heel rises was used for the analysis.

Standing on leg eyes closed

SOLEC has a low validity but good inter-test reliability for healthy people [17].

SOLEC was performed on a force platform (see "squat jump") and both maximum time standing on one leg and postural sway was measured. The participants stood on their dominant leg with the other knee flexed to 90 degrees in the knee and with their arms crossed over their chest. The test commenced when they closed their eyes and was stopped when the participant put the other foot to the ground or opened their eyes. After 60 seconds, the test was aborted automatically [18]. The time and the velocity of the centre of pressure (COP) in millimetres/second were assessed. The participants performed three trials of which the longest length of time and least sway velocity was chosen for analysis.

Grip strength

Grip strength has been tested on healthy participants and has shown a high intra-test reliability [19]. A grip meter (Sagitta) was used, and the result was measured in Newton (N). The handlebar was adjusted so the participants could comfortably hold the handle between the proximal and the distal joint of the finger. The manoeuvre was executed by elevating the arm to 90 degrees, flexing their elbow to 90 degrees and squeezing the handle as tight as they could while they flexed their upper body and extended their shoulder and elbow. The test leader did not encourage them, however they were urged to keep a constant pressure throughout the whole movement sequence. Three trials were allowed and the highest value was chosen for analysis.

Intervention

The intervention included three postural balance exercises that were performed bilaterally once a day 3x30 seconds/exercise for six weeks. The first exercise was standing on one leg with the arms flexed forward to 90 degrees in the shoulder as the torso was rotated as far as possible to the left and right (Figure 1a). The second exercise was standing on one leg while the person had their eyes closed and the other leg and both arms in any chosen comfortable position (Figure 1b). In the third exercise, the participant stood on one leg with the other leg extended at the hip and the knee. The arms were kept above the head and the body was kept straight while the upper body tilted forward and the leg lifted up in the air-called "the dragon" (Figure 1c). Each participant was expected to keep a journal to gauge compliance. After three weeks, the difficulty of the exercises was increased by standing on a folded towel.

Figure 1a. Exercise 1. Rotation of the torso whilst standing on one leg.

Figure 1b. Exercise 2. Standing on one leg with both eyes closed

Figure 1c. Exercise 3. Standing on one leg, tilting the upper body down and raising the back leg.

Statistics

To decide the number of participants required for this study design SJ was chosen as a main variable and a baseline was calculated on the first three participants included in this study. Five centimetres increased jump height was considered as a clinically significant improvement in SJ. The power was set to 0.8 and alpha to 0.05. Based on these the number of required participants was calculated to be 28.

Comparisons of outcomes pre- and post- intervention were made with a paired T-Test for normally distributed data and Wilcoxon´s test for the non-normally distributed data. Kolmogornov-Smirnov´s test was used to determine a normal distribution. The software was International Business Machine (IBM) SPSS version 20 for Windows. A p-value less than 0.05 was considered statistically significant.

Results

Twenty-nine people expressed an interest in participating in the study, two of which did not meet the inclusions criteria. Three did not come to the testing appointment, one participant dropped out due to lack of time and one person were excluded from the study because the person could not decide her amount of exercise sessions/week. The final number of participating persons tested before the intervention was 22. During the intervention two subjects dropped out because they stated that the exercises were too hard and affected their normal physical performance adversely. Two other participants suffered from ankle distortion before the post-intervention test. Another participant forgot to do the exercises in the intervention and was excluded. At post-testing the final number of participants were 17. Their mean age was 32.4 (sd± 9.9).

	Pre	**Post**	**P-value**
Squat jump (cm)	21.9 (sd±7.1)	24.0 (sd±7.9)	0.007
Heelrise (repetitions)	62.7† (min-max 16-175)	107.0† (min-max 29-363)	0.006
Postural sway (mm/s)	73.7 (sd±30.0)	61.0 (sd±18.8)	0.077
Grip strength (N)	421.1 (sd±124.5)	407.8 (sd±11.8)	0.181
Time in SOLEC (s)	36.8† (min-max 5-60)	47.7† (min-max 5-60)	0.018

Table 1. Mean values and standard deviations (sd) of pre-test and post-test for Squat jump, Heel rise, Postural sway, Grip strength and time in Standing on one leg eyes closed (SOLEC).

†Median value with corresponding dispersion measure.

The Kolmogorov-Smirnov test confirmed a normal distribution of jump height, postural sway in SOLEC and maximal power in grip strength. Maximum time in SOLEC and number of heel rise repetitions were normally distributed before the intervention but not after.

The meanvalue centimetres in squat jump increased from 21.9 to 24 centimeters. The medianvalue in SOLEC and repetitions in heelrise increased (36.8-47.4 seconds, 62.7-107 repetetions). All with a statistically significance. The meanvalue for postural sway in SOLEC and strength in grip strength both decreased (73.7-61 mm/s and 421-407 Newton) however none of these values were statistically significant.

Discussion

The results of this study indicate that adult healthy athletes can improve their local muscle function with regards to strength and endurance by PBT exclusively.

Even though postural balance was trained the sway did not decrease significantly while the jump height and endurance did. It might be that an increase in strength will appear before sway decreases or that postural balance involves several physical aspects necessary for balance ability improves due to requirement of a more sophisticated neuromotor regulation for controlling sway. For regulation, coordination of the several muscles is required which might take a longer time to train and develop [20, 21]. It might also be that the training period was too short or postural sway is too difficult to improve for already active adult athletes. Behm et al [1] found that PBT improved postural balance after five weeks of training. Considering that the intervention in this study was conducted over a period of six weeks, it would have been expected also in this study.

Another reason can be that these healthy adults need a certain amount of postural sway to regulate postural balance. More challenging balance tasks would give more information in this regard.

The exercises in this study were chosen specifically to work against the body weight alone and no additional weights were applied. Also, the exercises were performed with the knee in extension not allowing for dynamic muscle work around the thigh with strong postural muscles such as the quadriceps. Even if there were static exercises, strength gains for dynamic components improved. The improvements in strength are suggested to be due to local neuromuscular adaptation. Hypertrophy was not assumed and not measured. As there was unchanged grip strength, no improvements in the central drive could be an explanation for the gains in muscle function.

Lower extremity endurance increased as measured by the number of repetitions of heel rises and an increased time in SOLEC. According to the principle of specificity, this was expected and confirmed.

In previous studies, the effects of PBT were as a result of longer workouts, fewer times per week and for a period of four weeks [11-13]. Participants in this study had shorter training sessions, nine minutes per day, and therefore a longer intervention period was chosen. The time for each exercise was short (30 seconds) in order to decrease the risk of negative side effects such as muscle fatigue. Despite this, two participants who dropped out of the study stated fatigue as a reason.

It may seem like a low load shouldn´t affect the muscles in the lower extremities to that extent, especially since the participants in this study were physically trained. However, Bisson et al [22] has shown that static training generates more fatigue than isokinetic exercises, which is another reason for the choice to train only 30 seconds. Since training was performed on a daily basis it may have interfered with their normal training routine.

The total training volume in this study was 70 minutes/week. This in contrast to the load/duration in previous studies which often used fewer sessions/week [11-13] but up to an hour per session giving an effective total training volume of 120-180 minutes/week [11-13]. Despite the fact that the load in our study was lower than in previous studies, it did produce an improvement in strength, which is argued to be the first adaption to occur during PBT. In earlier research, Kean [13] incorporated a design resembling ours (80minutes/week) and were able to detect and increase in strength. A similar duration of 60minutes/week showed that PBT could equalize a difference in strength between the weak and the strong leg in tennis players [23]. However Sannicandro et al [23] used exercises with an external load from rubber bands and medicine balls.

A 5 centimeter´s difference on the SJ could be considered as a relatively high effect size. In the literature no real minimum difference for SJ is presented, which is why 5 centimeters was chosen based on clinical perspective and experience. This study did not reach up to the required number of participants and therefore, the insignificant results should be interpreted with caution. Another limitation was that the study did not have a control- or reference group. This means that results cannot be compared to a natural progression.

Several participants were not able to flex their knees to 90 degrees, often due to reduced mobility in the ankles. This could result in a decrease in force development in the quadriceps due to the shorter lever arm, thereby resulting in a lower SJ value, but this would affect both the pre- and post-tests.

The compliance was fairly high with an average of 35 sessions, to a maximum of 42. Despite this, the number of non-completed sessions may have affected the result negatively i.e. no effects on muscle function from PBT. This means that the improvements in this study could be underestimated.

The participants were not informed of their results to avoid an increase in effort just to have better results at the post-test. They could though have counted and remembered the number of heel rises in order to keep track of their progress. Therefore the test leader did not encourage them during any of the tests.

Conclusion

Even though postural sway was not improved in this experimental study, the result supports that it is possible to improve local muscle functions such as explosive strength and endurance in healthy, adult athletes by only utilizing regimes for postural balance training.

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