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Research article

Balance Training Exercises Decrease Lower-Limb Strength Asymmetry in Young Tennis Players

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Abstract

The issue of functional asymmetries in the lower-limbs has been the subject of numerous recent investigations concerning many different contact, limited-contact and non-contact sports. The presence of strength asymmetries in the lower-limbs of young athletes practicing various sporting disciplines is considered an intrinsic risk factor for injury; in such cases, compensation strategies should thus be implemented aimed at eliminating, or at least limiting, the degree of asymmetry in order to avoid the negative consequences asymmetries can have upon the health of young sportsmen and women on the long-term. The aim of the present study was to examine the presence of functional asymmetries in the lower-limbs of young tennis players in strength and speed drill performance and to test a specific balance-training programme in its capacity to effectively reduce such asymmetries. Twenty-three young tennis players were randomly assigned to the Experimental Group (EG) (n = 11: 4 females, 7 males; 13.2 ± 0.9 years; 50.8 ± 8.9 Kg; 1.63 ± 0.08 m) or Comparison Group (CG) (n = 12: 4 females, 8 males; 13.0 ± 0.9 years; 51.1 ± 9.2 Kg; 1.61 ± 0.09 m). To quantify percent asymmetries in lower-limb strength before (T0) and following (T1) training, performances were assessed in the one-leg hop test (OLH), side-hop test (SH) and side steps and forward 4.115-m test (4m-SSF). Performances in the 10 and 20m sprint tests and the Foran test were also assessed. The EG completed a total of 12 training sessions directed at balance training: two 30-minute sessions/week over a 6-week period. The CG followed an identical training schedule, but training sessions consisted of tennis-specific drills only. The results reveal significant differences between pre- and post-training tests in the EG only: the degree of lower-limb asymmetry was decreased in the EG following completion of the training programme, as assessed using the OLH test ($p < 0.001$), SH test ($p < 0.001$) and 4m-SSF test ($p < 0.05$). A significant interaction and main effect of training was also observed in the EG: balance training led to a significant reduction in the percent of asymmetry in lower-limb strength, as measured using the SH ($p < 0.01$), 4m-SSF ($p < 0.01$) and OLH ($p < 0.05$) tests. These results confirm that balance training exercises are able to counteract/reduce the degree of asymmetry in lower-limb strength in young tennis players.

Key words: Strength asymmetry, risk of injury, speed, lateral/side movements.

Introduction

Functional asymmetries in the lower-limbs have been the subject of numerous recent investigations concerning many different contact, limited-contact and non-contact sports aimed at understanding the role of conditioning in performance and in injury prevention (Fousekis et al., 2010; Impellizzeri et al., 2007; Lawson et al., 2006; Newton et al., 2006; Sannicandro et al., 2011a; 2011b; Stephens et al., 2005). Functional asymmetries in the lower-limbs are determined by strength deficits between the two limbs (Fousekis et al., 2010) and differ from muscular imbalances, which represent an alteration in the strength relationship between agonist and antagonistic muscle pairs (Jones and Bampouras, 2010; Knapik et al., 1991; Schlumberger et al., 2006).

In children and adolescents that practice sport at either the recreational or competitive level, the presence of strength asymmetries between the two lower limbs is correlated with a high risk of injury (Hickey et al., 2009). In the presence of functional asymmetries in young athletes, compensation training programmes should be undertaken aimed at eliminating, or at least limiting, the asymmetries in order to avoid negatively affecting the health of young athletes on the long-term. For instance, Emery et al. (2006) showed that 50% of subjects who had suffered knee injuries 20-25 years earlier presented signs of knee osteoarthritis compared to just 5% of the sample population who had not suffered any prior knee injury.

Tennis is characterised by the execution of a series of high intensity and explosive actions, very brief sprints, changes of direction and abrupt deceleration (Fernandez-Fernandez et al., 2010; Fernandez et al., 2005; Girard and Millet, 2004); these specific movements put the tennis player under physical stress. In young and adult tennis players presenting lower-limb functional asymmetries in strength capacity resulting from the practice of sport-specific movements (Ellenbecker et al., 2009), personalised and specific training should be provided to minimise this risk factor for injury.

Over recent years, athletic conditioning programmes have started to introduce balance training exercises, which may involve the use of resistances, with the aim of reducing risk of injury (Anderson and Behm, 2005; Caraffa et al., 1996; Gioftsidou et al., 2006; Granacher et al., 2011; Malliou et al., 2004; 2010; Olsen et al., 2005; Wedderkopp et al., 2003; Yaggie and Campbell, 2006). The introduction, and now widespread use, of training techniques involving the use of unstable surfaces (i.e. balance training) represents an important methodological innovation in sports training and therapy (Behm, Anderson, 2006). Exercises performed on unstable surfaces may be included into a training programme as part of an injury prevention/management strategy or with the primary aim of improving athlete performances, especially in relation to team and open skill sports. An unstable surface places an increased demand on the neuromuscular system to

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stabilise the joints involved in the execution of a movement. All of the advantageous effects of the movements performed on unstable surfaces have beneficial outcomes in sport-specific performances; for instance, in tennis, the correct activation of core muscles achieved when performing balance training exercises is a prime example of the positive transfers that can be obtained in the execution of sport-specific movements, from weight lifting to hitting a tennis ball (Behm and Colado, 2012; Behm et al., 2010). However, the relationships between training on unstable surfaces, injury prevention and the reduction of strength asymmetries are not yet completely clear (Behm et al., 2010a).

The aims of this study were (i) to examine the presence of functional asymmetries in the lower-limbs of young tennis players in strength and speed drills; (ii) to verify whether balance training provides an effective programme able to reduce functional asymmetries.

Methods

Participants

The study was performed using a sample of young tennis players (n = 23); the players were randomly divided into an Experimental Group (EG) (n = 11: 4 females, 7 males; mean age, 13.2 ± 0.9 years; mean weight, 50.8 ± 8.9 Kg; mean height, 1.63 ± 0.08 m) and a Control Group (CG) (n = 12: 4 females, 8 males; mean age, 13.0 ± 0.9 years; mean weight, 51.1 ± 9.2 Kg; mean height, 1.61 ± 0.09 m).

This study conforms to the policy statement relating to the Declaration of Helsinki. Before data collection, all subjects and their parents provided their informed consent in accordance with the Institutional Ethics Committee for the Department of Clinical and Experimental Medicine of the University of Foggia, Italy.

Functional capacities

Specific tests were used to evaluate functional asymmetries between the lower-limbs in strength and speed drill performance:

one-leg hop test (OLH) (Augustsson et al., 2004; Gustavsson et al., 2006), for the evaluation of explosive strength and stability in the sagittal plane;

side hop test (SH) (Docherty et al., 2005; Gustavsson et al., 2006), for the evaluation of strength and stability in the frontal plane;

10 and 20m sprint tests, from a standing start position, for the evaluation of acceleration in a straight line; the two sprint tests were carried out separately and test two different elements of speed capacity, as previously employed in a similar study (Girard and Millet, 2009);

Foran test (Foran, 2001), for the evaluation of acceleration with a change of direction;

side steps and forward 4.115-m test (4m-SSF) (Salonikidis and Zafeiridis, 2008), for the evaluation of lateral speed by means of lateral sprints.

The tests of acceleration and speed were performed with the assistance of photocells (TTsport, San Marino). All tests were performed in the tennis court where the athletes regularly played tennis. Each subject's leg preference was determined by asking the athlete to perform a one-legged jump, as previously defined in the literature (Brophy et al., 2010). In the tests of leg strength, the subject's dominant leg was assessed first, followed by the non-dominant leg. In order for the participants to familiarise themselves with the tests, two practice trials were performed with an interval rest time of 2 minutes. For both groups (EG and CG), testing was conducted before (T0) and after (T1) the completion of the 6-week training period.

The order of presentation of the tests was as follows:

On the first (T0) and penultimate day of training (T1): one-leg hop test, side hop test and Foran test.

On the second (T0) and last day of training (T1): 10-20m sprint test, side steps and forward 4.115-m test.

Training programme

The EG completed two 30-minute sessions per week dedicated to balance training. The two weekly training sessions proposed to the EG were differentially structured (see Tables 1 and 2 for details); balance training was performed after a 15 minute warm-up consisting of slow running, stretching and speed exercises and preceded the execution of sport-specific exercises.

The CG followed a programme that consisted of tennis-specific drills only; once again, two 30-minute sessions were performed per week for a total of 12 sessions (i.e. 6 weeks).

Statistical analysis

For both groups, the degree of asymmetry between the dominant (D) and non dominant (ND) leg in performances in the one-leg hop test (OLH) (Augustsson et al., 2004; Gustavsson et al., 2006), the side hop test (SH) (Docherty et al., 2005; Gustavsson et al., 2006) and side steps and forward 4.115-m test (4m-SSF) (Salonikidis and Zafeiridis, 2008) was calculated applying the formula:

Table 1. Balance training session 1.

Exercise	Task	Sets x repetitions	Recovery time
1.Balance and stability	High skipping with single leg halt every 5 skips.	6 x 5 per limb	20 sec
2.Balance and strength	4 diagonal single-legged bounds, maintaining equilibrium before the last bound for 3 sec.	4 x 6	30 sec
3. Balance and strength	6 forward bounds, maintaining equilibrium before the last bound for 3 sec.	3 x 4 per limb	45 sec
4. Balance and strength	10 low rows using an elastic exercise band bound to a support performed against a bipodalic inflatable disk.	4 x 10	45 sec
5. Balance and strength	2 Kg medicine ball chest passes whilst balancing on a bipodalic inflatable disk.	4 x 10	2 min
6. Balance and strength	2 Kg medicine ball chest passes with torsion whilst standing on one leg.	4 x 6 (twice per limb)	2 min

Table 2. Balance training session 2.

Exercise	Task	Sets x repetitions	Recovery time
1.Balance and stability	Lateral raises (2 Kg dumb-bells) whilst standing on one leg on a Bosu balance trainer	3 x 10	2 min.
2.Balance and strength	Balancing on an inflatable Skimmy cushion (Sixtus, Italy) for 30 sec.	2 x 4 per limb	30 sec.
3. Balance and strength	4 two-legged successive jumps on the ground from an inflatable disk, maintaining landing position for at least 3 sec.	4 x 4	30 sec.
4. Balance and strength	Step-ups on a Bosu balance trainer.	4 x 10	30 sec.
5. Balance and strength	Two-legged squats on unstable surface (Temix, Erregroup, Italy).	3 x 10	1 min.
6. Balance and strength	Step-ups on a Bosu balance trainer whilst grasping 4 Kg dumb-bells.	4 x 8	45 sec.

1-(ND*100/D) (Yamamoto, 1993). Descriptive statistics (M±SD) were calculated for percent asymmetry results, as well as for the results of all other tests; a confidence interval (95% CI) was also used to present the magnitude of the deviation from the mean. Kolmogorov-Smirnov tests were used to determine whether data sets were normally distributed. The null hypothesis for the Kolmogorov-Smirnov test states that the data are normally distributed; thus data were considered as arising from normal distributions for p-values greater than 0.05. For intra-group comparisons (pre- *vs*. post-training test results for both EG and CG), paired T-tests were used. Two-way ANOVA was used to examine the data of both groups together (i.e. EG and CG) for the pre- and post-training time points (T0 *vs*. T1) in order to determine the main and interactive effects of training. Statistical significance was considered for $p < 0.05$. The statistical package SPSS 12.0 for windows (SPSS Institute, Chicago, IL) was used to analyse all data.

Results

For both groups, the Kolmogorov-Smirnov test gave values of P>0.05, confirming the normal distribution of the data. The descriptive statistics (M±SD) and confidence intervals (95%CI) of percent asymmetry in lower-limb strength, as assessed using the OLH, SH, 4m-SSF, Foran and 10-20m sprint tests, are reported in Table 3.

Significant effects of training (T0 *vs*. T1) were only found in the EG; balance training significantly reduced percent lower-limb asymmetry measured using the OLH, SH and 4m-SSF tests. No intra-group differences were revealed for the EG in mean performance in the Foran test, or in the 10 and 20m sprint tests. No statistically significant differences were identified in the CG in percent asymmetry measured using the OLH, SH, 4m-SSF, Foran or 10-20m sprint test.

ANOVA with repeated measures revealed: i) a significant ($p < 0.01$) interaction and main effect of training upon percent asymmetry measured using the SH and 4m-SSF tests ($F_{1,21}$ = 15.253, $p < 0.01$, partial η^2 0.42 and $F_{1,21}$ = 12.394 $p < 0.01$, partial η^2 0.37, respectively) and ii) a significant ($p < 0.05$) difference in percent asymmetry measured using the OLH test (F1.21 = 6.698, $p < 0.05$, η^2 0.24).

Discussion

The aim of the study was to investigate the levels of functional strength asymmetry in the lower-limbs of young tennis players. The values of strength asymmetry assessed using the OLH and SH were significantly diminished in the EG and lead us to propose the hypothesis that the balance training exercises employed were efficacious in improving the athletes' control of ground reaction force (Russell et al., 2007) and their level of control and capacity to stabilise the lower-limb in the frontal plane. Indeed, balance training intensifies proprioception by stimulating the proprioceptors to provide feedback for the maintenance of balance and the detection of body position (Cug et al., 2012).

The pre- and post-training results of the SH test demonstrate that the changes in the values of asymmetry in this study are coherent with those arising in analogous studies of other open-skill sports and sports that involve asymmetry in the upper-limbs (Sannicandro et al., 2010). The significant reduction in lower-limb asymmetry observed in the EG subjects was attained through the use of balance training exercises that required a high level of joint control on both the sagittal and frontal planes, and tasks that used either body weight alone or small hand weights. Indeed, unstable surfaces are able to enhance

Table 3. Mean scores (M±SD) and confidence interval (CI) by group and time of assessment.

	Time of Assessment							
	T0				T1			
	EG		CG		EG		CG	
Variables	**(M±SD)**	**95% CI**	**(M±SD)**	**95% CI**	**(M±SD)**	**95% CI**	**(M±SD)**	**95% CI**
% asymmetry OLH (cm)	9.0 (3.6)	6.5-11.4	9.0 (3.7)	6.6-11.3	3.7 (1.5)***	2.6-4.6	9.3 (5.2)	6.0-12.6
% asymmetry SH (cm)	10.8 (5.9)	6.8-14.8	13.2 (10.1	6.7-19.6	3.2 (1.4)***	2.3-4.1	13.0 (8.1)	7.8-18.1
% asymmetry 4m-SSF (s)	7.2 (5.0)	3.8-10.6	10.1 (3.0)	8.2-12	2.7 (2.3)*	1.1-4.3	12.9 (5.3)	9.5-16.3
Foran test (s)	5.8 (.3)	5.6-6.1	6.2 (.5)	5.9-6.6	5.7 (.1)	5.6-5.8	6.2 (.5)	5.8-6.6
10m sprint (s)	2.5 (.1)	2.4-2.6	2.6 (.2)	2.5-2.8	2.5 (.1)	2.4-2.6	2.6 (.2)	2.5-2.8
20m sprint (s)	4.0 (.5)	3.6-4.3	4.4 (.5)	4-4.8	4.0 (.3)	3.8-4.3	4.4 (.5)	4.0-4.7

EG= Experimental Group; CG= Comparison Group; T0= pre-training test; T1= post-training test; OLH= one-leg hop; SH= side hop; 4m-SSF= 4.115-m side steps and forward. * $p < 0.05$; *** $p < 0.001$ compared with EG T0.

intermuscular coordination between agonist and antagonist muscles, permitting improved control of joint position and reduced joint stiffness (Behm and Colado, 2012). Furthermore, the balance training exercises force the subjects to distribute load (body weight) uniformly between the two limbs: only in this way can subjects correctly perform the tasks. If body weight is not distributed evenly between the two limbs whilst performing dynamic exercises on unstable surfaces, the exercise would be brought to an end by the subject falling off the assigned surface.

The results of ANOVA for repeated measures show that the training protocol followed by the EG led to significant reductions in the observed values of functional asymmetry, bringing them within the range of normality (Noyes et al., 1991). The degree of functional asymmetry observed in the lower-limbs of the sample of individuals studied lies at the limit of the cut-off level, beyond which it would constitute an element of injury risk (Noyes et al., 1991; Petsching et al., 1998).

The adaptations induced by balance training also enhance the dynamic expression of balance due to the use of joint stability exercises on different planes and with reduced flight phase; this component is able to reduce the stabilisation time of the lower-limb following a flight phase, as recently demonstrated in the literature (Ebben et al., 2010).

The reduction in the stabilisation time constitutes an additional advantage deriving from the use of unstable surfaces and represents an indicator of improved control. Indeed, the time employed by the subject to become stable following a flight phase is considered to be a valid indicator of control (Ebben et al., 2010; Wikstrom et al., 2006) and represents an aspect that is significantly stimulated by the performance of various functional strength exercises (Ebben et al., 2010).

Functional improvements and decreased injury rates as a result of balance exercises are often discussed in association with adaptations in neuromuscular control mechanisms, such as proprioception or spinal reflex activity (Hewett et al., 2002). The reduction in asymmetry obtained by the EG in this study is consistent with the results obtained in another similar study using balance training in professional football players (Sannicandro, 2008): just 16 training sessions were able to reduce the values of functional asymmetry to values that were lower than the cut-off values indicated in the literature (Sannicandro, 2008). Although the relationship between balance ability and sports injury risk has been clearly established (Hrysomallis, 2011), few studies have examined the relationship between balance training and athletic performance in specific sporting disciplines; the few studies present in the literature are limited to rhythmic gymnastics (Calavalle et al., 2008) and refer to young female athletes only (Boldon et al., 2012).

The results for the tests of acceleration in a straight line (10 and 20 metres) and with a change in direction (Foran test) reflect the fact that balance training only has very modest effects upon levels of maximal and explosive strength, as previously indicated in the literature (Behm and Colado, 2012; Bruhn et al., 2004; Cressey et al., 2007). Scientific evidence shows that when movements are performed on highly unstable surfaces, no advantageous transfer is observed in maximal strength or explosive strength – factors that influence performance in sprinting from a standing position (Behm et al., 2010).

The values obtained by the EG in the 4.115-m side steps and forward test (4m-SSF), however, highlight a significant reduction in post-training (T1) functional asymmetry compared to pre-training results (T0). This trend was not observed in the CG; in fact, a higher mean level of limb asymmetry was observed in the post-training 4m-SSF test compared to pre-training levels (Table 4), although the difference did not quite achieve statistical significance ($p = 0.06$). This result is coherent with the results emerging from the assessment of strength asymmetry, considering the nature (typology) of the 4m-SSF test, in which the subject is required to sprint laterally, pushing predominantly with just one of the two limbs – the external leg. Indeed, asymmetry in the explosive strength capacities of the lower-limbs exerted in the frontal plane may condition lateral sprinting performance, which in practice consists of a succession of leaps along the frontal plane

Conclusion

The planning of athletic conditioning in young tennis players requires that strength in the lower-limbs is evaluated such that appropriate injury prevention strategies may be inserted into training programmes, as already confirmed in the literature (Malliou et al., 2010). The presence of possible strength asymmetries between the lower-limbs in tennis players constitutes, apart from a potential long-term risk factor, an effective limit upon sport-specific speed performance. The analysis of functional asymmetries in young tennis players requires further investigation, especially in light of a theoretical model recently described in the literature (Fousekis et al., 2010) and considering the maturation of balance capacities in young athletes (Granacher et al., 2011).

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Key points

- The determination of functional asymmetries in the lower-limbs has been the subject of numerous recent investigations aimed at the prevention of injuries in many different contact, limited-contact and non-contact sports.
- Sport-specific movements in tennis impose different loads upon the two lower-limbs and can cause the development of lower-limb strength asymmetries in young tennis players.
- The planning of athletic conditioning in young tennis players requires that strength in the lower-limbs is evaluated such that appropriate injury prevention strategies may be inserted into training programmes.
- Balance training exercises, and indeed all tasks performed on unstable surfaces, lead to benefits in sport-specific performance.

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