THE EFFECT OF AGILITY TRAINING ON ATHLETIC POWER PERFORMANCE

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Abstract:

The purpose of this study was to determine the effects of agility training (training of acceleration, deceleration and quick change of the direction of movement) on athletic power performance. Eighty healthy male college students (age 19±1.1 years; body mass 77.2±7.1 kg; body height 180.1±7.1 cm; body fat percentage 10.8±1.6) participated in this study. The study was a randomized controlled trial. The subjects were assigned randomly to an experimental group (EG; n=40) and control group (CG; n=40). Statistically significant differences were determined within the experimental group both in the initial and in the final measurement ($p<.05$), whereas significant differences were found between the experimental and the control group in the final measurement ($p<.05$). Changes in muscle power were assessed through the jumping height in a counter-movement jump (CMJ). The experimental group significantly ($p<.05$) improved in the jumping height in CMJ (43.17 vs 44.01 cm), counter-movement jump from the left leg (CMJ1L) (29.66 vs 30.12 cm) and counter-movement jump from the right leg (CMJ1R) (28.77 vs 29.11 cm). The values achieved by the subjects from the experimental group ranged from low values for the standing long jump (SLJ), to moderate values for the counter-movement jump (CMJ), to high values for the 5m sprint (SP5). To enhance explosive muscle power and dynamic athletic performance, complex agility training can be used. Therefore, in addition to the well known training methods such as resistance training and plyometric training, strength and conditioning professionals may efficiently incorporate agility training into an overall conditioning programme of athletes striving to achieve a high level of explosive leg power and dynamic athletic performance.

Key words: *muscle function, leg extension, reaction*

Introduction

For high-level competition efficiency it is necessary to have adequate motor abilities, as well as appropriate heart function, maximum oxygen uptake, etc. Their importance varies from sport to sport because they should correspond to the demands of a given sport. The majority of sports have in their structure different changes of direction. The ability that is used in such movement patterns is called agility. Pauole, Madole, & Lacourse (2000) found significant correlations between performance in an agility *t*-test and in 40-yard sprint time in both men and women. In contrast, Buttifant, Graham, & Cross (1999), as well as Young, Hawken, & McDonald (1996) reported no significant correlations between straight sprinting and agility speed tests in either Australian soccer or Australian Rules football players. Furthermore, both Draper & Lancaster (1985) and Mayhew, Piper, Schwegler, & Ball (1989) reported low common variances of 21% between tests for straight sprinting speed and agility. Interestingly, Young, McDowell, & Scarlett (2001) examined the specificity of the training response to straight sprint or agility training over a 6-week period and found that a training method specific to one speed quality produced limited transfer to the other. Mayhew, et al. (1989) reported a common variance of 21% for the 40-yard time and an agility test containing five changes of direction in forward, sideways, and backward running. Further, these investigators conducted a factor analysis on several fitness test results and found the speed and agility tests to be represented by different factors. This meant that speed and agility had little in common statistically, leading the authors to conclude that these were relatively independent qualities. To conclude, agility is highly dependent on coordination and movement control but apart from coordination there is a substantial number of factors that affect the level of agility such as mobility of joints, dynamic balance, power and flexibility, level of energy resources, strength, speed and optimal biomechanical structure of movement. Some authors present agility as the ability which makes it possible for an athlete to change direction, make quick stops and perform fast, smooth, efficient and repetitive movements (Miller, Herniman, Ricard, Cheatham, & Michael, 2006). When we look at the same problem in a wider context, agility can be termed *speed coordination*. In terms of specific situational conditioning some sports use the term *specific agility*, because it has specific movement patterns. Basic methodology of agility training implies the learning of a basic walking technique, running technique, change of direction, jumps and landings (Wroble & Moxley, 2001). These are basic movement structures which are of vital importance for successful participation in any sport. If the movement technique is better, the athlete achieves better effects of a training process and is more effective in competition. Drop jump, counter-movement jump and plyometric training can positively affect vertical jump efficiency, as well as agility performance (Thomas, French, & Hayes, 2009). It was stated by Kukolj, Ropret, Ugarković, & Jarić (1999) that "both maximal jumping and sprinting are generally considered as dynamic movements requiring high muscle power and, therefore should be closely related" and because agility performance is also a dynamic movement requiring high muscle power, it is reasonable to assume that jumping and agility performance would be closely related. Being aware of the complexity of agility as a motor ability and of agility training, the purpose of this study was to determine whether agility training can have positive effects on athletic power performance.

Methods

Subjects

Eighty healthy male first-year college students were randomly assigned either to the experimental group (EG; n=40) (age 19±0.9 years; body mass 76.2±6.1 kg; body height 181.1±7.3 cm; body fat percentage 10.7±0.9) and to the control group (CG; n=40) (age 18±1.6 years; body mass 77.2±6.9 kg; body height 180.1±4.1 cm; body fat percentage 10.7±1.3). All participants were physically active (they were all physical education students) and had sufficient experience in explosive physical activities which imply agility as a dominant motor ability. In accordance with the University of Zagreb Guidelines for the use of Human Subjects, all measurement procedures and potential risks were explained to each participant prior to obtaining their written informed consent. The protocol of the study was approved by the Ethical Committee of the Faculty of Kinesiology, University of Zagreb according to the revised Declaration of Helsinki.

The weekly volume of regular physical activity of subjects ranged from between 8 and 10 hours.

Study design

The study was carried out during the spring semester of the 2003/2004 academic year. The subjects underwent a two-week testing period at the beginning and at the end of the experimental period, and the testing was carried out by experienced professionals, members of the Sport Diagnostic Centre at the Faculty of Kinesiology University of Zagreb. The study was a randomized controlled trial. During the testing period the air temperature ranged from 21°C to 27°C. The control group was instructed to maintain regular activities and to avoid any strenuous physical activity during the course of the study. The subjects in the experimental group completed a 10-week exercise training programme on every second day, i.e., 3 days a week with a break of 1 week in the middle of the study. The tests were carried out in the week before and the week after the 10-week training period. All the practice and testing took place at the same time of the day to control any circadian variation in performance. In order to prevent any hindering effects that could emerge as a result of the process of learning a particular task and that could consequently confound the results of the study, all individuals participated in a 1-week period familiarization with the testing protocol before the initiation of the study to accustom themselves to the testing and training procedures. The subjects expressed 100% compliance with the exercise training programme.

Testing procedure

In order to evaluate the effects of agility training on power performance, we applied a testing procedure that included measurements of 9 power performance tests. Agility requires rapid force development and high power output, as well as the ability to efficiently utilize the stretch-shortening cycle in ballistic movements (Plisk, 2000). Leg muscle power has been moderately correlated with agility (Mayhew, et al., 1989). Since, as already said, vertical jump and agility performance can

Table 1. *The plan of the experiment and testing*

Initial testing 2 weeks	5 weeks of training period/ 3 times a week for 60 min	Control testing 1 week	5 weeks of training / 3 times a week for 60 min	Final testing 2 weeks

be positively affected by a drop jump and counter-movement jump, as well as by plyometric training, this information encouraged the authors of this paper to study whether agility training can effect athletic power performance. The counter-movement jump (CMJ) was performed in a similar way to the standing long jump (SLJ), except that the subject was instructed to perform an unconstrained vertical jump from a standing upright position that includes the initial counter-movement (Komi & Bosco, 1978). The force platform measurements were used to calculate the muscle power as a product of the vertical component of the ground reaction force and velocity of the centre of mass (Dalleau, Belli, Viale, Lacour, & Bourdin, 2004). The velocity was obtained from the integral of the acceleration provided by the force signal, whereas the final result was the muscle power averaged over the propulsive jump phase (i.e., the time interval from the instant of the velocity turning upward to the end of the feet's contact with the platform). The vertical component of the measured ground reaction force also served for the calculation of the jump height. The subjects executed a counter-movement jump from the left (CMJ1L) and from the right (CMJ1R) leg, i.e., a vertical jump with a preparatory descent in a half-squat position, and after that a quick jump phase from one leg followed without any arm swing. Counter-movement tests were carried out by using the Quattro jump platform (Kistler, Switzerland). A result was represented by the height of the jump measured in centimetres (cm). Standing jumps were measured by using a tape measure that had a measurement scale printed on it (Elan, Slovenia). The results in the long jump test represented the distance in centimetres of a jump measured from the toes before the actual jump and the heel after the jump, executed with an arm swing and from a standing position (Marković, Jukić, Milanović, & Metikoš, 2007). The subjects performed the SLJ, as well as the SLJ1L and the SLJ1R on a long jump mat (Elan, Slovenia), and the distance from the starting point to the landing point at heel contact with the surface was used as the result. Sprinting performance was assessed using a 5m sprint (SP5), a 10m sprint (SP10) and a 20m sprint (SP20). The test was performed from a standing start and measured by means of infrared photocells (RS Sport, Zagreb, Croatia). Initially the subject stood with his rear (swing) leg on a contact mat. He was instructed to accelerate as quickly as possible through the timing gate positioned 20 metres from the starting line. The movement of the rear leg from the contact mat initiated a digital timer (resolution .001 sec). All tests used in this study were reliable and had good metric characteristics (Marković, Dizdar, Jukić, & Cardinale, 2004). As already said, the participants were randomly assigned to two groups of 40, and each group was tested separately between 10:00 a.m. and 13:00 p.m. on 3 separate days (Monday, Wednesday and Friday). The first testing session included the sprint tests, and the second testing session included the jumping tests. All tests were performed in a random order at the beginning of the spring semester and at the end of the experimental period. The subjects were instructed to avoid any strenuous physical activity during the duration of the experiment and to maintain their dietary habits throughout the whole duration of the study. The jump tests were preceded by a 15-minute warm-up that included running indoors for 5 minutes at a pace chosen by the subjects and was followed by callisthenics and the execution of 10 squats, 10 heel raises and a 2-5 min stretching period. Each subject executed 3 trials in each test, with a break between trials of around 1 minute. The break between the two tests in one testing session was around 7-8 minutes.

Training procedure

The experimental group was asked to perform three sessions of agility training per week on every second day (i.e., on Monday, Wednesday and Friday) for 10 weeks. Thus, the programme included 30 training workouts for each subject in the experimental group. One week of recovery was introduced between the two 5-week cycles (see also Table 1). Training sessions in the experimental group lasted 60 minutes and began with a standard 15-minute warm-up: 5 minutes of jogging, calis-thenics exercises, squats, heel raises and stretching. The whole agility training programme was performed on an indoor athletic running track. The training programme employed by the experimental group is outlined in Table 2. However, to be able to evaluate the selective effects of agility training we decided not to include the conditioning training in this study.

Statistical analysis

First, the means and standard deviations were calculated. The reliability of all muscle function and athletic performance tests was expressed by intra-class correlation coefficients (ICCs) and coefficients of variation (CVs). The ICCs were calculated from the repeated measures analyses of variance (ANOVA), whereas the CVs were derived by the two-way ANOVA in the following way – the participants represented a random effect, the number of tests in sequence was a fixed effect, whereas the log-transformed performance measure was the dependent variable. The mean CV was calculated from the root mean square error (RMSE) using the following formula: CV _ 100 (eRMSE _ 1) _ 100 _ RMSE (Hopkins, 2000). The 95% confidence intervals both for the ICCs and the CVs were also calculated. The magnitude of changes in the two groups was compared using a one-way ANOVA

Table 2. Agility training programme for the experimental group

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Duration of training	Init.	Init.	60	60	60	60	60	60	60	60	60	60	Fin.	Fin.
Learning movement technique of direction-changing task			+	+	+	+								
Frontal agility			+	+	+	+	+	+	+	+	+	+		
Lateral agility			+	+	+	+	+	+	+	+	+	+		
Agility with changing direction of movement up to 90°					+		+		+		+			
Agility with changing direction of movement up to 90° and more						+		+		+		+		
Horizontal and vertical agility						+	+	+	+	+	+	+		
Agility in random reaction tasks							+	+	+	+	+	+		

Legend: Init. – Initial measurement; Fin. – Final measurement

on the difference between the groups in such a way that the initial result was subtracted from the final one. When significant treatment effects occurred, the Tukey *post hoc* tests were employed to locate the specific significant differences between the experimental and the control group. The level of statistical significance was set at $p<.05$. The effects of training within each group were assessed using the Dunn's multiple comparison procedure incorporating the Bonferroni correction to maintain the family-wise type I error rate at .05. By using the Bonferroni correction, the .05 significance level was divided by 3 (3 *t*-tests), yielding a type I error rate of .0167 for each *t*-test. The magnitude of treatment effects both within and between groups was estimated with the Cohen's effect size (ES) (Thomas, Lochbaum, & Landers, 1997). The within-group ES is defined as the difference between the post-mean and the pre-test mean divided by the pre-test SD (Thomas, et al., 1997). The between-groups ES is defined as the difference between the experimental group post-test mean and the control group post-test mean divided by the control group pre-test SD (statistical analysis was done according to Marković, et al., 2007).

Results

The CVs and ICCs for all the selected tests ranged between .9 and 3.1% (95% confidence interval, .7–3.3%) and between .88 and .91 (95% confidence interval, .82–.96), respectively, indicating a high absolute and relative reliability. There were no statistically significant differences either between the control and the experimental group in the initial measurement or between the initial and the final results for the control group. Statistically significant differences were determined for the experimental group between the initial and the final measurement ($p<.05$), as well as between the control and the experimental group in the final measurement ($p<.05$). No significant difference in the training effects in any variable was found for the control group between the initial and the final measurement. The changes in the final measurement of athletic performance are presented in Table 3. The experimental group significantly ($p<.05$) improved in all sprint tests – SP5 (4.2%; ES _ .5), SP10 (3.9%; ES _ .4), and SP20 (3.0%; ES _ .3). In all counter-movement tests ($p<.05$) and standing long jump tests ($p<.05$) significant improvement was detected in the experimental group. The values achieved by the subjects in this group ranged from small values (i.e., ES _ .1– .3; CMJ power), to moderate (i.e., ES _ .4–.7; CMJ1L and CMJ1R power), and to high values (i.e., ES _ .9; SLJ, SLJ1R, SLJ1L). The changes in muscle power were determined by the changes in the height of the counter-movement jump. The jumping height of the counter-movement jump significantly ($p<.05$) improved in the experimental group (5%; ES _ .6), CMJ1L (7.5%; ES _ .8) and CMJ1R (6.3%; ES _ .5). Significant improvement ($p<0.005$–0.001) (4-9%; ES _ 0.2-0.4) for all standing long jump tests was found only in the experimental group, and this improvement was significantly greater (p _ .05) than in the control group. As for the significantly higher treatment effects observed in the experimental group compared to the control group, the values ranged from low ones (SLJ), to moderate (CMJ) and finally to high values (SP5).

Discussion and conclusions

All tests had high ICCr reliability coefficients, the reliability values being the greatest in the CMJ tests. The results presented here reveal an exceptionally high reliability of all selected muscle function and athletic performance tests. In particular, CVs and ICCs together with their corresponding 95% confidence intervals indicated high within-individual and between-individual reliability. This can be explained partly by an extensive familiarization of the subjects with the testing procedures before the initiation of the

Table 3. Results of the experimental and the control group in the initial and final measurement

Variable	Initial measurement		Final measurement	
	CG	EG	CG	EG
Mass (kg)	77.2±6.9	76.2±6.1	77.3±6.9	76.5±6.1
Body fat %	10.7±1.3	10.7±.9	10.6±1.4	10.8±1.0
SP5 (s)	1.12 ± .13	1.09 ± .12	1.11 ± .11	1.06 ± .03**
SP10 (s)	1.87 ± .14	1.86 ± .13	1.87 ± .23	1.77 ± .09**
SP20 (s)	3.14 ± .16	3.15 ± .17	3.09 ± .19	3.02 ± .09**
CMJ (cm)	43.27 ± 5.30	43.17 ± 5.20	43.17 ± 5.22	44.01 ± 3.22**
CMJ1L (cm)	29.76 ± 4.04	29.74 ± 4.00	29.66 ± 4.13	30.12 ± 3.00**
CMJ1R (cm)	28.98 ± 3.83	28.96 ± 3.82	28.77 ± 3.67	29.11 ± 2.63**
SLJ (cm)	187.28 ± 13.53	187.18 ± 13.43	187.16 ± 13.48	188.58 ± 9.22**
SLJ1L (cm)	172.07 ± 14.33	172.12 ± 14.24	172.06 ± 14.14	173.37 ± 8.11**
SLJ1R (cm)	167.69 ± 14.97	167.58 ± 13.88	167.66 ± 14.87	168.29 ± 9.34**

*Values are expressed as mean ± SD

** Statistically significant at p<.05 for experimental (EG) and control group (CG) in the final measurement

Legend: SP5 – 5m sprint; SP10 – 10m sprint; SP20 – 20m sprint; CMJ – counter-movement jump; CMJ1L – counter-movement jump from the left leg; CMJ1R – counter-movement jump from the right leg; SLJ – standing long jump; SLJ1L – standing long jump from the left leg; SLJ1R – standing long jump from the right leg

study. Moreover, in this case, the sample size within each group considerably exceeded the usual sample size in studies evaluating training intervention programmes. Specifically, to the authors' knowledge this is the first study dealing with analysing the effects of agility training on athletic power performance. The sample size is one of the factors directly influencing the power of detecting the real and meaningful effect in treatment studies (Thomas & Nelson, 1990). In this case, for both within-group and between-group comparisons statistical power (1) exceeded .7 for medium effect sizes (mean difference / SD _ .5), supporting the appropriateness of the sample size applied. This study evaluated the selective effects of a 10-week agility training programme on athletic power performance in physically active men. The main result of this study is associated with the agility training–induced changes in athletic power performance. In particular, it was demonstrated that a 10-week agility training programme significantly improved leg extensor power (Table 3). These findings are not in compliance with those obtained by Draper & Lancaster (1985) and Mayhew, et al. (1989) who reported low common variances of 21% between tests for straight sprinting speed and agility. Interestingly, Young, et al. (2001) examined the specificity of the training response to straight sprint or agility training over a 6-week period and found that a training method specific to one speed quality produced limited transfer to the other. Delecluse (1997) found maximal speed and acceleration to be specific qualities in sprint athletes. However, field sport athletes are believed to have different running mechanics from sprint athletes (Pauole, et al., 2000), and significant correlations between acceleration and maximum speed in professional rugby league players have been reported (Baker & Nance, 1999). Pauole, et al. (2000) found significant correlations between performance in an agility *t*-test and the 40-yard sprint time in both men and women. The results of this study are in compliance with the results of Pauole, et al. (2000) – positive effects were determined between agility training and power performance. In contrast, Buttifant, et al. (1999), as well as Young, et al. (1996) reported no significant correlations between straight sprinting and agility speed tests in either Australian soccer or Australian Rules football players. Because agility is often represented in the same context with speed, this could be the reason why improvement in sprinting performance was detected in the subjects from the experimental group in the final measurement, but the specificity of the sample must be considered. Several studies have reported correlations between straight sprint tests and various agility tests. But, when a correlation coefficient (r) is lower than .71, the shared or common variance between the two variables is less than 50%, indicating that the tests are specific or somewhat independent in nature (Thomas & Nelson, 1990). Common variances of 11% and 22% have been reported, respectively, for straight sprints and a soccer agility test (Buttifant, et al., 1999), and the Illinois agility test (Draper & Lancaster, 1985). Mayhew, et al. (1989) reported a common variance of 21% for the 40-yard time and an agility test containing 5 changes of direction in forward, sideways and backward running.

Further, these investigators conducted a factor analysis on several fitness test results and found the speed and agility tests to be represented by different factors. This meant that speed and agility had little in common statistically, leading the authors to conclude that speed and agility were two relatively independent qualities. In this study the results indicate that agility can effect sprinting and jumping performance which could lead us to the conclusion that these abilities are linked together, and dependable on one another. Agility training with a specific task that combines reaction to a specific signal resulted in improvement in athletic power performance. In particular, it appears that the improvements in jumping (but also in sprint and agility) performance as a result of agility training could be partly the result of improved leg extensor power (Baker & Nance, 1999). Therefore, it is possible that the agility training used in this study could have improved the subjects' jumping performance primarily by improving muscle coordination. However, this is only an assumption, because the recorded parameters do not provide the basis for a more specific interpretation of the obtained results. The greatest improvement was detected in EG in the SP5, CMJ1L and SLJ1L. We can conclude that agility training has a positive effect on movement technique (Sayer, 2000) and the ability to produce force in leg muscle more efficiently (Rimmer & Sleivert, 2000). Single leg movement improves intra- and inter-muscular coordination, which results in a better athletic power performance in sprinting and jumping tasks (Adams, 1984; Paterno, Myer, Ford, & Hewett, 2004). This is one of the reasons why the subjects from the experimental group had better results in the SP5, CMJ1L and SLJ1L tests. To enhance explosive muscle power and dynamic athletic performance, complex agility training can be used. Because of that agility exercises are usually used at the start of the main part of a training session when the body is at full work rate. The training session should consist of short intervals of intense workload (3-10 sec) and appropriate intervals of rest. Therefore, agility training directly affects the nervous and muscular systems and needs a certain time to regenerate (Buttifant, et al., 1999). The findings of this research indicate that agility training can also be used effectively as a training method for improving explosive leg power and dynamic athletic performance. Hence, in addition to the well-known training methods such as resistance training and plyometric training, strength and conditioning professional athletes may incorporate agility training well into an overall conditioning programme of athletes striving to achieve a high level of explosive leg power and dynamic athletic performance. The data here represent a rather novel finding that could be of considerable importance for improving the training methods aimed at enhancing athletic power performance in sport through agility training.

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UTJECAJ TRENINGA AGILNOSTI NA EKSPLOZIVNA SVOJSTVA SPORTAŠA

Cilj ovog rada bio je utvrđivanje učinaka treninga agilnosti (trening akceleracije, decelaracije i brze promjene pravca kretanja) na eksplozivna svojstva sportaša. Uzorak ispitanika za ovo istraživanje sačinjavalo je 80 zdravih studenata (dob 19±1.1 godina; tjelesna masa 77.2±7.1 kg; tjelesna visina 180.1±7.1 cm; postotak potkožnog masnog tkiva 10.8±1.6) prve godine Kineziološkog fakulteta Sveučilišta u Zagrebu. Ispitanici su slučajnim odabirom raspoređeni u eksperimentalnu (n=40) i kontrolnu (n=40) skupinu. Utvrđene su statistički značajne razlike između inicijalnog i finalnog mjerenja kod eksperimentalne grupe (p<.05), dok je samo u finalnom mjerenju utvrđena statistički značajna razlika između eksperimentalne i kontrolne grupe ispitanika. Promjene u eksplozivnim svojstvima ispitanika utvrđivane su pomoću testa skok s pripremom (CMJ). Eksperimentalna je grupa statistički značajno (p<.05) povećala visinu skoka u testu *skok s pripremom* (43.17 naprama 44.01 cm), skok lijevom nogom s pripremom (29.66 naprama 30.12 cm), skok desnom nogom s pripremom (28.77 naprama 29.11 cm). Vrijednosti rezultata koje su postigli ispitanici u eksperimentalnoj skupini varirali su od niskih vrijednosti kod skoka u dalj s mjesta, preko umjerenih vrijednosti kod skoka s pripremom, pa do visokih vrijednosti kod sprinta na 5 metara. Iz dobivenih rezultata ovog istraživanja može se zaključiti kako se provođenjem kompleksnog treninga agilnosti mogu značajno unaprijediti eksplozivna svojstva sportaša. Stoga, kondicijski treneri mogu za unapređenje eksplozivne snage donjih ekstremiteta u svoje programe trenažnog rada, osim već otprije poznatih metoda treninga, kao što su trening s opterećenjem i pliometrijski trening, uvrstiti i trening agilnosti.

Ključne riječi: *mišićna funkcija, ekstenzija nogu, reakcija*