EFFECT OF A SPECIFIC STRENGTH TRAINING ON THE DEPTH SQUAT WITH DIFFERENT LOAD: A CASE STUDY.

Ciacci S., Pecoraioli F.

Faculty of Exercise and Sport Sciences, University of Bologna, Italy
Dept. of Histology, Embryology and Applied Biology, University of Bologna,Italy

The purpose of this study is to verify if a specific strength training program can reduce the transition time from descent to ascent phase in squat exercise. The kinematic and temporal data of 3 depth squats with different load (35%, 40%, 45% of 1RM) during 2 test sessions, before and after a specific strength training program, have been collected.
The Track and Field 400 m Italian Champion have been analysed during the depth squat through an optoelectronic stereophotogrammetric system for tridimensional motion analysis. The collected data were: knee and hip angles, time of eccentric and concentric phase (descent and ascent times), the transition time (from descent to ascent phase).
The results show that a specific strength training can develop the speed of movement and, particularly, decrease the transition phase time at heavy load. This method can be useful to search an optimal depth squat load and to develop the Stretch Shortening Cycle (SSC) speed.

KEY WORDS: strength training, transition phase, 3d kinematic analysis, SSC time, sprint ability.

INTRODUCTION: The strength training is a fundamental component for the optimal performance in several sport (Rahmani 2001, Gollhofer 2003, Wisloff 2004, Harris 2008), especially in the sprint (Sleivert 2003, Harris 2008, Holm 2008). The squat is the most investigated strength exercise and the most used movement in strength training for the leg. The researchers studied this exercise in order both to explain the sport performance (Wisloff 2004, Harris 2008) and to prevent injuries (Escamilla 2001).
The squat parameters that the researchers studied, were: kinematics data (knee and hip angles and their angular velocity), temporal values (time of SSC), kinetics (joint moments) and EMG data (Rahmani 2001, Manabe 2007, Harris 2008).
The special strength training can improve the load used during a squat exercise or its stretch-shortening cycle speed (Rahmani 2001, Sleivert 2003, Manabe 2007, Harris 2008). The SSC speed, especially the short transition phase from eccentric to concentric phase, are fundamental to improve the powerful push off (Gollhofer 2003) and the sprinting performance (Sleivert 2003). Previous studies demonstrated that a powerful push off is possible only if the time of the SSC and especially of the transition phase are short (Manabe 2006, Gollhofer 2003). The purpose of this study is to verify if a specific strength training can improve the speed of depth squat exercise and, particularly, its transition time.

METHODS: The Track and Field 400 m National Italian Champion (183 cm high, 71 kg weight, personal best on 400 m, 46.30 s) have been analysed through an optoelectronic stereophotogrammetric system for tridimensional motion analysis. (VICON 460, Oxford Metrics, UK). The data were collected using six infrared 1.3 megapixel cameras, with a 100 Hz sampling frequency. A modified Helen Hayes marker set was used with the addition of a marker on the head of the fifth metatarsal and one marker on the trunk.
The subject performed 2 depth squat at 3 different loads (30%, 35%, 40% 1RM) all at maximum speed, before and after a special strength training program (4 training week). This program included 3 workouts for each week, except for the 4^{th} (only 2 workouts). During each workout the athlete performed 4 set of 3 movements of depth squat with loads included between the 30% and 60% of 1RM, combined with 4 set of countermovement or drop jump.
During the test and the training, to standardize the exercise the barbell's movement have been checked through 2 marks on the bar supports.

Data collected were: angles and angular flexion/extension velocities of knee and hip joint and the SSC time (descent/eccentric, ascent/concentric an transition phase time).
The descending phase was defined as the period of movement from maximum bar height before the descent to the lowest point of the squat; the ascending phase was defined as the period from the lowest point of the squat to maximum bar height after ascent. The transition phase was defined as the period of the movement from the last millimetre of knee and hip markers in vertical and horizontal axis during the descent phase to the first millimetre of the same markers during the ascending phase, according to the system accuracy. During the transition phase the knee angle supposedly stays the same (Bosco et al. 1981).

RESULTS: In table 1 are reported the time of the different phases (Eccentric=ECC, Transition =T.P. and Concentric phase=CONC) at each load and the Range of Motions (ROM) of the knee joint during both test session (Pre-test and Post-test, before and after the training, respectively). The results show the speed development of the movement during the Post-test (Table 2). Particularly, the speed development is notable at 87 and 97 Kg of load, while at 77 kg the data appear very similar.

Table 1:

KNEE	Pre-test					Post-test				
30% 1RM	ECC. 1/100s	T.P. 1/100s	CONC. 1/100s	TOT 1/100s	ROM Deg.	ECC. 1/100s	T.P. 1/100s	CONC. 1/100s	TOT 1/100s	ROM Deg.
Average	59	38	62	121	102	59	33	61	120	98
SD	4	3	1	4	4	3	8	3	3	5
	Pre-test					Post-test				
35% 1RM	ECC. 1/100s	T.P. 1/100s	CONC. 1/100s	TOT 1/100s	ROM Deg.	ECC. 1/100s	T.P. 1/100s	CONC. 1/100s	TOT 1/100s	ROM Deg.
Average	63	48	72	135	101	55	40	67	122	100
SD	3	3	2	2	1	1	3	1	1	3
	Pre-test					Post-test				
40% 1RM	ECC. 1/100s	T.P. 1/100s	CONC. 1/100s	TOT 1/100s	ROM Deg.	ECC. 1/100s	T.P. 1/100s	CONC. 1/100s	TOT 1/100s	ROM Deg.
Average	66	61	78	144	98	62	51	66	128	95
SD	6	1	5	2	1	4	4	1	5	4

In table 2 are reported the differences between the data before and after the training. The grey colour underline the developments obtained in the post-test session.

Table 2:

KNEE JOINT DIFFERENCES					
% 1RM	ECC. 1/100s	T.P. 1/100s	CONC. 1/100s	TOT 1/100s	ROM Deg.
30%	0	-6	-1	-1	-4
35%	-8	-8	-5	-13	-1
40%	-4	-10	-12	-16	-3

The ROM of the knee results are very similar in both session tests and are comparable with the same data of others studies (Domire Z.J. 2007), confirming that the developments have been obtained in the speed of movement. A similar study (Manabe 2007) show the knee and hip joint ROM shorter than the same data of this research and consequently also the time of movement are shorter.
The same values of hip joint are collected in Table 3. Also about this joint, the greater developments of the speed have been notable in the post-test session. Table 4 shows the better performance obtained from the athlete during the post-test session, especially in the heaviest load squat. It's interesting to notice that at the lightest load (30% of 1RM), the subject at post-test make the movement more quickly than pre-test, even if the ROM is greater.

Table 3

HIP	Pre-test					Post-test				
30%1RM	ECC. 1/100s	T.P. 1/100s	CONC. 1/100s	TOT 1/100s	ROM Deg.	ECC. 1/100s	T.P. 1/100s	CONC. 1/100s	TOT 1/100s	ROM Deg.
Average	54	53	73	127	66	56	45	68	124	75
SD	4	2	9	10	3	4	2	12	11	5
	Pre-test					Post-test				
35%1RM	ECC. 1/100s	T.P. 1/100s	CONC. 1/100s	TOT 1/100s	ROM Deg.	ECC. 1/100s	T.P. 1/100s	CONC. 1/100s	TOT 1/100s	ROM Deg.
Average	59	66	75	134	68	52	52	71	123	63
SD	4	3	3	2	3	0	2	1	1	13
	Pre-test					Post-test				
40%1RM	ECC. 1/100s	T.P. 1/100s	CONC. 1/100s	TOT 1/100s	ROM Deg.	ECC. 1/100s	T.P. 1/100s	CONC. 1/100s	TOT 1/100s	ROM Deg.
Average	60	77	83	143	63	59	57	69	128	66
SD	4	4	2	3	1	3	4	3	3	3

Table 4

HIP JOINT DIFFERENCES					
% 1RM	ECC. 1/100s	T.P. 1/100s	CONC. 1/100s	TOT 1/100s	ROM Deg.
30%	2	-8	-5	-3	8
35%	-7	-14	-4	-11	-5
40%	-1	-20	-14	-15	4

Also the angular velocities of the Flexion and Extension Peak at pre-test (FP1 and EP1 respectively) and the same data of post-test (FP2 and EP2 respectively) confirm the best performances obtained during the post-test (Table 5 and 6).

Table 5

°/sec	KNEE				HIP			
30%1RM	FP1	EP1	FP2	EP2	FP1	EP1	FP2	EP2
Average	321	324	355	376	294	210	332	248
SD $\pm$	59,8	19,5	87,3	5,9	26,3	12,1	32,5	11,1
35%1RM	FP1	EP1	FP2	EP2	FP1	EP1	FP2	EP2
Average	395	334	418	360	321	205	348	222
SD $\pm$	116,9	23	21,7	12,4	32,9	14,7	25,6	9,96
40%1RM	FP1	EP1	FP2	EP2	FP1	EP1	FP2	EP2
Average	357	319	358	345	285	212	312	216
SD $\pm$	86,8	15,4	120,9	12,4	25,4	25,8	44,1	5,8

Table 6

°/sec	Knee Differences		Hip Differences	
% 1RM	FP	EP	FP	EP
30%	-33,8	-51,7	-38,1	-38,1
35%	-23,3	-25,3	-27,5	-16,4
40%	-1,1	-25,6	-26,8	-4,0

DISCUSSION: The results show that the kinematic and temporal data of depth squat obtained in the post-test (after the specific strength training program) are better than the same collected in the pre-test session. The time of eccentric and concentric phase is shorter at each loads of post-test. Particularly is shorter the transition phase time; the development of this time was the most important aim of this study.

All the enhancements are more noticeable at the heavier loads. In fact the improvement at 30% of 1RM seems to be not very important; this can to mean that the load is too easy to influence positively the strength training and consequently the results of the test before and after the training are similar. Especially about the knee joint time the data show not important differences (table 2).
Whereas at 30% of 1RM, it is interesting to notice the improvement of the flexion and extension angular velocity of the knee and hip joint.
Instead at the 35% and 40% of 1RM loads the improvement are considerable about all parameters analysed. Especially the transition and concentric phase time are shorter in post-test than the same data in pre-test session.
Also the flexion and extension angular velocities of knee and hip joint are faster. These data underline how it is very important in the strength training the choice of the right load to improve a specific performance parameter.

CONCLUSION: The results show that the specific strength training can be useful to improve the speed of depth squat exercise. Especially the aim of the specific training used in this research was to improve the velocity of the transition phase from descent/eccentric to ascent/concentric phase. In fact the others studies assert that if the transition phase is slower or delayed, no enhancement of the concentric phase occurs (Gollhofer 2003) with a consequent loss of power. The results of this study showed that this specific strength program resulted helpful to develop the transition phase of the squat in the observed athlete.
However in this study only 1 subject was analysed, therefore the conclusions are limited. To generalize the results of this research, it is necessary to analyze a sample including more athletes. But after this research seems to be possible to confirm the others studies of the literature that assert that the shorter SSC and the correct load in the squat exercise are decisive elements to improvement the special strength and the sprint performance (Rahmani 2001, Sleivert 2004, Harris 2008).

REFERENCES:

Bosco C., Komi, P.V., Ito, A. (1981) Prestretch potentiation of human skeletal muscle during ballistic movement Acta Physiol Scand, 111, 135-140.

Domire, J.Z., Challis, J.H. (2007) The influence of squat depth on maximal vertical jump performance. *Journal of Sport Sciences*, 25(2), 193-200.

Escamilla, R.F. (2001) Knee biomechanics of the dynamic squat exercise. *Med. Sci. Sports Exerc*, 33,1,127–141.

Gollhofer, A., Bruhn, S., (2003). The biomechanics of jumping. *In: Gollhofer, A., Bruhn, S. (Eds.), Handbook of Sports Medicine and Science: Volleyball. Blackwell Science Pub Publisher*, 3, 18-28.

Harris, N.K., Cronin, J.B., Hopkins, W.G., Hansen, K.T. (2008) Squat jump training at maximal power loads vs. Heavy loads: effect on sprint ability. *J Strength Cond Res* 22(6), 1742-1749.

Holm, D.J., Stalbom, M., Keogh, J.W.L., Cronin, J. (2008) Relationship between the kinetics and kinematics of a unilateral horizontal drop jump to sprint performance. *J Strength Cond Res* 22(5), 1589-1596.

Manabe, Y., Shimada, K., Ogata, M. (2007) Effect of slow movement and stretch-shortening cycle on lower extremity muscle activity and joint moments during squat. *J Sports med Phys Fitness*, 47,1-12.

Rahmani, A. Viale, F., Daleau, G., Lacour, J.R. (2001) Force/velocity and power/velocity relationships in squat exercise. *Eur J Appl Physiol,* 84, 227-232

Sleivert, G., Taingahue, M. (2004) The relationship between maximal jump-squat power and sprint acceleration in athletes. *Eur J Appl Physiol,* 91, 46-52.

Wisløff, U., Castagna, C., Helgerud, J., Jones, R., Hoff, J. (2004) Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. *Br J Sports Med;* 38:285–288.