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IOANNIS KESOGLOU¹, GEORGIOS TSIGGANOS²,
POLYXENI ARGEITAKI², SMIRNIOTOU ATHANASIA²

¹ *Research Institute for Sport and Exercise Science,
Liverpool John Moores University*

² *Department of Physical Education and Sport Science,
University of Athens*

ABSTRACT

The aim of this study was to examine the effects of a resistance training session which incorporated light loads and high intensity contractions on performance variables associated with soccer. Six male university soccer players participated in this study. A counterbalanced within-subject repeated measures design was used to evaluate the impact of a resistance training session on maximal isometric force (MVIC), vertical jump height (VJH), muscle soreness (MS) and muscle activation (MA). Following an acute standardized resistance training session each subject was randomly allocated to an experimental condition which incorporated either 1 day of passive rest (C1) or 2 days of passive rest (C2). Following the rest period a soccer-specific protocol was completed. A recovery period of at least one week was provided between trials. All measurements were obtained before and immediately upon completion of the resistance training session and at 24 hrs and both 24hrs and 48 hrs following the completion of the training session in (C1) and (C2) respectively. The main findings of this study were that high velocity/low load training produced no significant differences in any of the measured variables in either 1 or 2 day/s recovery conditions.

KEY WORDS: *soccer performance, resistance training, muscle soreness, isometric force, twitch interpolation, vertical jump.*

INTRODUCTION

The observable increases in competitive soccer fixtures have led to uncertainty regarding the impact of resistance exercise on training regimes to optimize performance. Soccer is an intermittent sport consisting of periods of low, moderate and high intensity workloads (4). The activity pattern is characterized by approximately 1350 discrete movement changes during a game, with the mean duration of any activity being 4-6 sec. A mean total of nineteen sprints are performed, with a sprint occurring once every 4-5 min. Four sec are spent running intensely and approximately 28 sec are spent on more aerobic activities (24, 32). This activity pattern requires international soccer players to have a high maximal oxygen uptake ($VO_2\text{max}$) of between 55-68 $\text{ml kg}^{-1}\text{min}^{-1}$ (22, 38). Additionally, a variety of more anaerobic skills such as changing speed, jumping, cutting and kicking are exhibited, all of which require a high degree of strength to be performed explosively and repeatedly (39, 39, 40).

Wisloff et al. (38, 39) highlighted the importance of maximal strength to soccer performance. In these studies, conducted on soccer-players, a very high correlation between sprint performance and jumping height with one maximum repetition (1RM) was reported. In agreement with Wilsoff et al. (38, 39), Hoff (23), also stressed the relationship between 10m sprint times and (1RM) squats, illustrating the importance of well developed strength in the legs of soccer players.

Resistance training is a prerequisite in increasing maximal strength, strength endurance, power and speed via adaptative physiological responses in the musculoskeletal and neuromuscular systems (13, 14, 35). Consequently sports such as soccer, in which these components of physical fitness are an important characteristic, have incorporated resistance exercises into periodization training programmes.

The pre-season provides an opportunity to concentrate a greater amount of time towards the 'development' of strength and the key components it underlies e.g. power and speed (21). Moreover, pre-season training plays an important role in injury prevention (2). In-season, the objective of resistance training is predominantly to 'maintain' strength levels via resistance training which consist an effective method of improving muscular fitness (20).

Another consideration for the coach in-season is the force/velocity specificity to include in resistance training sessions to induce the appropriate adaptations to enhance or maintain performance variables. Training programmes designed to produce the greatest hypertrophy are often characterized by loads of approximately 70% (1RM), whilst programmes designed to improve strength through increased neural coordination are commonly typified by intensities of 85%-100% (1RM) (10). Therefore, if performed in-season when insufficient

rest time is available, this type of heavy load training may compromise competitive performance (8, 9, 18). It is not well documented how other modes of resistance loading could enhance or maintain muscle strength without the concomitant associated negative effects (e.g. fatigue and DOMS). Previous studies have reported that a resistance training mode which utilizes high contraction velocities with high/low loads improves strength and power (12, 16, 19, 35, 36). The use of lighter training loads ($< 45\%$ 1RM) have been reported that improve strength in contrast to heavy loads but also enables greater velocities and accelerations to be achieved (10), which is related better with the type of athletic activities performed during a 90min soccer play. Nevertheless, little is known regarding the fatigue effects on subsequent competitive performance using this mode of training in-season. The aim of this study was to examine the impact of a resistance training session which incorporated light loads and high intensity contractions on performance variables associated with soccer.

SUBJECTS

Six male university soccer players with resistance training experience volunteered to take part in the study (mean \pm SD: age 24 years \pm 3; mass 76 kg \pm 8; height 1.78 m \pm 0.3). All individuals gave their written informed consent to participate and all procedures were fully explained. Liverpool John Moores University's ethics committee granted ethical approval. Subjects maintained a normal diet and were asked to refrain from vigorous exercise and alcohol consumption during the course of the study. All individuals had no history of disease or musculo-skeletal abnormality and none were under any pharmacological treatment.

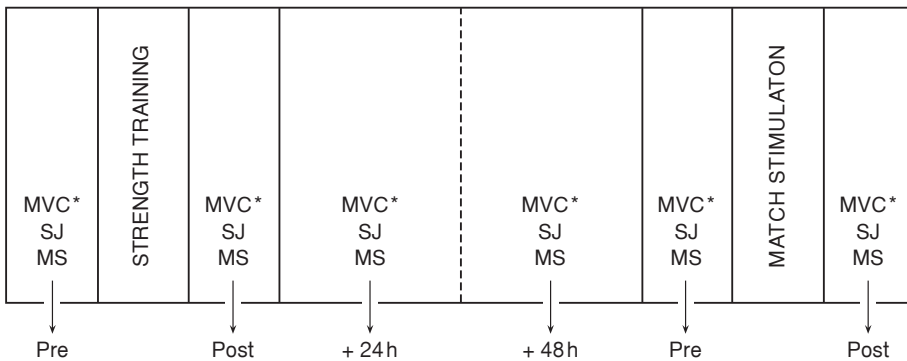
Pre-Experimental procedures

Approximately 10 days prior to the actual experiment, subjects completed full familiarisation on all experimental procedures. Subjects visited the laboratory several times (5 ± 2) to be familiarized with the procedure of performing isometric quadriceps force with and without twitch interpolation. These familiarisation sessions continued until the subject's Maximal Voluntary Isometric Contractions (MVIC) force and voluntary activation demonstrated repeatable results (33). All subjects were familiar with the exercises used for the strength training programme. Subjects were specifically engaged in squat exercises. The weight selection to estimate the 1RM was based on each subject's previous weights used for training and was chosen in order to fatigue the subject in less than eight repetitions. This protocol has been used in predicting 1RM and has been shown to be valid and reliable (5).

Experimental design

A counterbalanced within-subject repeated measures design was used to evaluate the impact of a resistance training session on physiological parameters related to athletic performance. Following an acute standardized resistance training session (see below); each subject was randomly allocated to an experimental condition which incorporated either 1 day of passive rest (C1) or 2 days of passive rest (C2) in a cross-over fashion. Following the rest period a soccer-specific protocol (see below) was completed. A recovery period of at least one week was provided between conditions to minimize any bias due to fatigue (3).

Prior to the completion of the resistance training session, perceived muscle soreness (MS) was assessed using a Visual Analogue Scale (VAS) to indicate the presence of any muscle damage. Next, Maximal Voluntary Isometric Contractions (MVIC) were performed to measure the force of each participant’s quadriceps musculature. During these contractions twitch interpolation was superimposed on to the (MVIC) to evaluate voluntary muscle activation. This technique was used to highlight whether any reduction in force resulted from central fatigue or from peripheral mechanisms (6). Subsequently, Vertical Jump Height (VJH) was measured via countermovement jump squat to provide an assessment of muscle function. This measurement incorporates the stretch shortening cycle which naturally occurs during sporting performance. Furthermore, has the ability to assess fatigued muscle (27). All of these measurements were obtained immediately upon completion of the resistance training session. Additionally, all measurements were recorded at 24 hrs and both 24hrs and 48 hrs following the completion of the training session in (C1) and (C2) respectively, and pre and post 90 min soccer-specific intermittent exercise



Schematic illustration of the experimental design. Each subject performed three squat jump (VJH) and three MVCs with twitch interpolation () in each session. Soreness scale (MS) completed within and between days.*

Resistance Training Session

The training protocol incorporated a squat movement (until 90° knee's angle) and emphasized high speed/ high power weight training. This involved lifting relatively weights as quickly as possible (1, 19, 36) and was focused on rapid hip extension. Subjects lifted a weight approximately equal to 40% of 1RM for the squat and completed 4 sets of 4-6 repetitions (10). A recovery period of 3-5 min between sets was allocated to allow full recovery. Prior to commencement of the training session, subjects completed a standardised warm-up which included 5 min of motorised treadmill running at a self-selected speed. Additionally, 1 set of 10 repetitions of squatting exercise was performed using only the Olympic bar (7). Hamstring, quadriceps and calf stretches were also included.

Maximal Voluntary Isometric Contractions and Twitch Interpolation

Maximal Voluntary Isometric Contractions

Subjects remained seated in a testing chair with the trunk vertical and a 90° flexion in the hip and knee. Velcro straps were placed across the thorax to prevent any extraneous body movements. Force was measured from the ankle where the attachment was connected to a strain gauge. After a warm-up period, each subject performed three trials of 100% (MVIC) (4s duration) during which supra-maximal twitches were superimposed. The force signal was A/D converted with a sampling frequency 1.000 Hz. Data were acquired for 8 seconds and analyzed with a commercial designed software program (AcqKnowledge III. Biopac Systems, Massachusetts).

Twitch Interpolation

As previously described by Morton et al. (33), the quadriceps were electrically stimulated using two moistened surface electrodes (Chattanooga, USA, 7 × 12.7 cm) which were positioned over the vastus lateralis and distally over the vastus medialis. Skin preparations for each electrode included shaving and light abrasion of the skin, followed by cleansing with an isopropyl alcohol swab. The electrodes position was marked to minimize electrode placement variability (25). Eight single square wave electrical impulses (100µs) were delivered during the 8 seconds sampling period. Each impulse was computer driven and was delivered at 250 V (Digimeter DS & Hertfordshire, UK). Two impulses were delivered before and after the contraction. The remaining four impulses were delivered during the (MVIC) and tested the maximality of each (MVIC). Each subject's superimposed current was previously determined during familiarization sessions and corresponded to 10% above the level required to evoke a resting twitch of maximal amplitude.

Activation Levels

Voluntary activation was calculated to provide representation of the ability to fully activate skeletal muscle during (MVIC). The interpolated twitch ratio (31) was used to calculate voluntary activation. As previously described by Morton et al. (33), the magnitude of the interpolated twitch was expressed as a ratio of the amplitude evoked by the same stimulus delivered to a relaxed potentiated muscle (see Eq. 1). The interpolated twitch was calculated by recording the average force during a 100 ms period before the application of each stimulus during the contraction and the maximal force during a 100 ms period after each stimulus. The highest mean pre-stimulus force (MVIC force) and the maximal post stimulus force were subsequently used for calculation of the magnitude of the interpolated twitch. Finally, the subtraction of the mean pre-stimulus force from the maximal post-stimulus force was used to calculate the interpolated twitch size.

Voluntary activation = $100 \{1 - (\text{size of interpolated twitch} / \text{size of resting twitch})\}$ (1)

Soccer-Specific Protocol

The soccer-specific intermittent exercise protocol that was completed consisted of 90-min of activity. This 90-min period was divided into 2×45 min identical blocks separated by 15-min intermission. The protocol was performed on a non-motorized treadmill (Woodway, Waukesha, Wisconsin, USA) and consisted of different exercise intensities that are similar to those observed during match-play (e.p. walking, jogging, cruising, sprinting). The proportions of the activities incorporated in the protocol were similar to those used by Drust et al (11). Each half (45 min) consisted of three identical 15 min cycles. This 15 min cycle was further sub-divided into three 5 min sub-cycles. Each 5 min activity cycle included 11 discrete bouts of activity: 3 static pauses, 3 bouts of walking, 3 bouts of jogging, 1 cruising and 1 sprint. The speeds that these activities were carried out at were: 4, 8, 12, no speed restrictions were placed on the sprinting as the subjects were instructed to produce a maximum effort (11).

Vertical Jump (Countermovement Squat Jump)

Subjects performed three trials in each session. The peak jump height was used as an indicator of the subject's jump performance. Jumps were performed with both feet placed shoulder width apart and with hands on hips while standing on a Jump MD platform (Takei Physical Fitness Test, Tokyo, Japan). Subjects were instructed to bend their knees and immediately jump

vertically as high as possible without pausing in the bent knee position (30). A 1 min rest period was provided between jumps.

Muscle soreness

A possible disadvantage of resistance training is the pain or discomfort (myalgia) often felt 24 to 72 hrs after exercising; which subsides generally within 2 to 3 days (9, 18, 28). This post-exercise soreness is also termed delayed-onset muscle soreness (DOMS). In the present study a Visual Analogue Scale (VAS) was used to assess perceived muscle soreness. The VAS is a horizontal line, 100 mm in length, anchored by word descriptors at each end, (Figure 2). The subjects marked a vertical line on the (VAS) that corresponded to their perception of their current perceived muscle soreness of the lower body. The (VAS) score was determined by measuring in millimeters from the left hand end of the line to the point that the subject placed a vertical line (37).

Statistical Analysis

Performance variables were analyzed using a within-subject two-factor ANOVA [Condition, 2 (1 recovery day vs 2 recovery days) and Time, 4 (pre-post resistance training and pre-post match simulation)] with repeated measures on time was used to analyze measured variables. The Greenhouse-Geisser correction was reported to the degree of freedom in order to correct for the potential violation of the assumption of sphericity. Pairwise comparisons were used to find were any significant differences occurred. Data were analyzed using SPSS for Windows (14.0 software package) and significance was set at $p < 0.05$. Values are expressed as mean and standard deviation.

RESULTS

Isometric Force

No significant difference in isometric force was found between conditions ($F_{1, 5} = 0.038$, $p = 0.852$, $p > 0.05$). Mean isometric force in the 1-day recovery condition was $570.69 \text{ N} \pm 102.37$ compared to $565.87 \text{ N} \pm 95.29$ in the 2-day recovery condition. Isometric force did not significantly differ over time ($F_{1.737, 8.687} = 0.821$, $p = 0.455$, $p > 0.05$). Isometric force pre-strength training was $556.98 \text{ N} \pm 113.24$. This value demonstrated a small increase in force $572.79 \text{ N} \pm 103.76$ when measured immediately post-strength training. Pre-match simulation isometric force was $567.53 \text{ N} \pm 91.38$ and increased slightly to 575.81 ± 93.60 immediately post-match simulation.

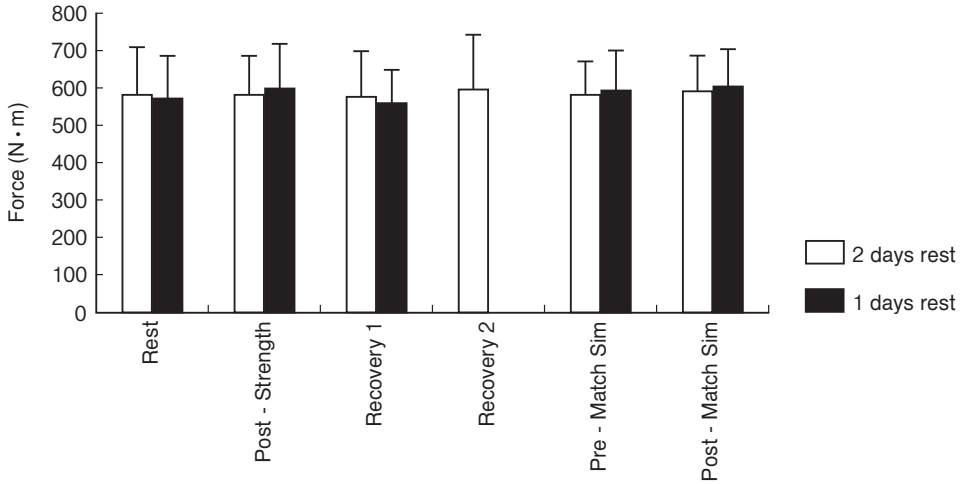


Figure 1: Maximal isometric voluntary contraction force (mean ± s).

Activation

No significant difference in muscle activation was found between conditions ($F(1, 5) = 0.015, p = 0.906, p > 0.05$). Mean muscle activation in the 1-day recovery condition was $97.62\% \pm 2.72$ in comparison to the 2-day recovery condition $97.78\% \pm 2.04$. Muscle activation was not significantly different over time ($F(2.230, 11.150) = 0.825, p = 0.475, p > 0.05$). Muscle activation remained relatively constant at all measured time points, with muscle activation recorded as $97.33\% \pm 2.70, 97.81\% \pm 2.69, 98.29\% \pm 1.57$ and 97.34 ± 2.59 at pre-strength, post-strength, pre-match and post match simulation time points respectively. There was no significant condition × time interaction effect ($F(1.808, 9.038) = 0.707, p = 0.505, p > 0.05$).

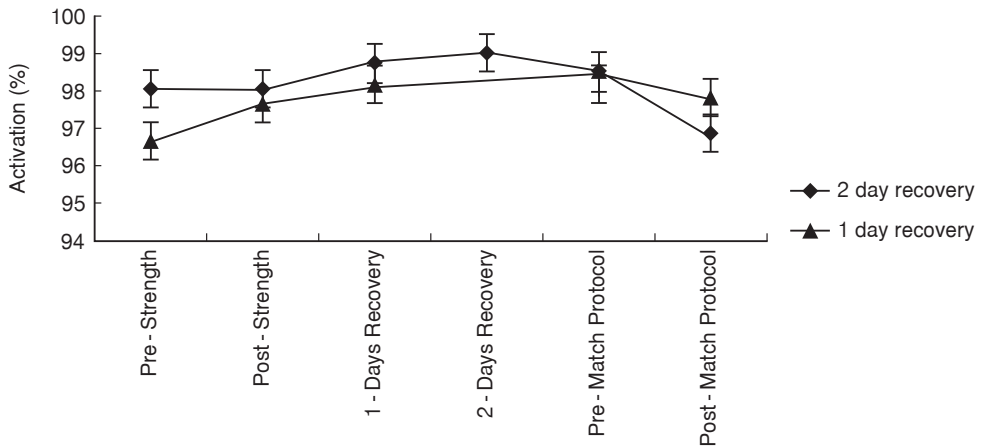


Figure 2: Muscle Activation (mean ± s).

Muscle soreness

No significant difference in muscle soreness was found between conditions ($F(1, 5) = 1.116, p = 0.339, p > 0.05$). Mean muscle soreness in the 1-day recovery condition was $7.21 \text{ mm} \pm 6.10$ compared to $8.92 \text{ mm} \pm 10.49$ in the 2-day recovery condition. Muscle soreness was significantly different over time ($F(1.500, 7.501) = 30.101, p = 0, p < 0.05$). Significant differences in muscle soreness occurred between pre-strength training and post-strength training, pre-strength and post-match simulation, post-strength training and pre-match simulation and pre-match and post-match simulation time points. Muscle soreness increased from a rating of 0 mm pre-strength training to a rating of $11.75 \text{ mm} \pm 4.45$ immediately post strength training. A decreased rating of $3.83 \text{ mm} \pm 4.06$ was reported pre-match simulation; with the greatest muscle soreness rating of $16.68 \text{ mm} \pm 9.42$ reported immediately post-match simulation. There was no significant condition \times time interaction effect ($F(1.297, 6.487) = 3.141, p = 0.120, p > 0.05$).

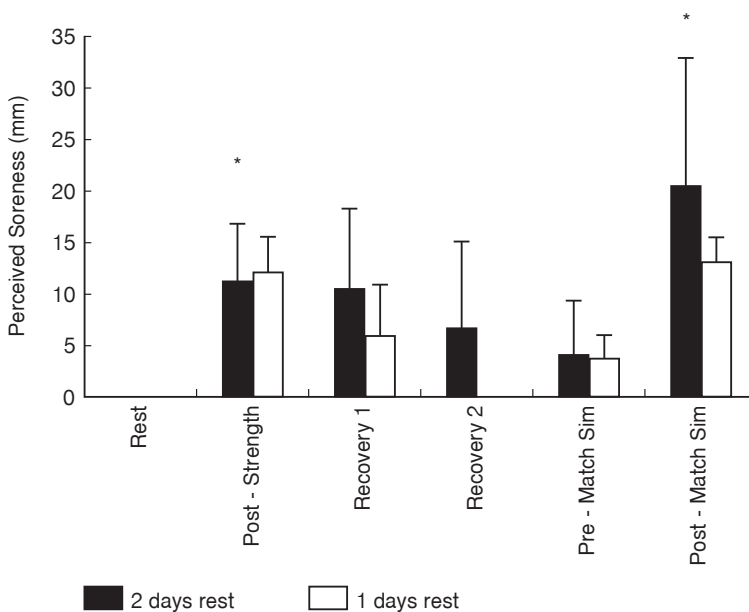


Figure 3: Ratings of muscle soreness (mean \pm s). * Significantly different from pre-strength exercise (excluding recovery days).

Vertical Jump

No significant difference in vertical jump height was found between conditions ($F(1, 5) = 2.168, p = 0.201, p > 0.05$). Mean vertical jump height in the

1-day recovery condition was $46.29 \text{ cm} \pm 3.41$ compared to $46.88 \text{ cm} \pm 3.93$ in the 2-day recovery condition. Vertical jump height significantly differed over time ($F_{1.654, 8.271} = 4.564$, $p = 0.051$, $p < 0.05$). A significant difference in vertical jump height occurred between pre-strength training and pre-match simulation. Vertical jump height was $45.75 \text{ cm} \pm 3.52$ pre-strength training compared to $45.92 \text{ cm} \pm 3.58$ immediately post-strength training. Pre-match simulation vertical jump height was $47.83 \text{ cm} \pm 3.88$ compared to $46.83 \text{ cm} \pm 3.87$ immediately post-match simulation. There was no significant condition \times time interaction effect ($F_{1.293, 6.465} = 1.869$, $p = 0.389$, $p = > 0.05$ (see Fig. 4).

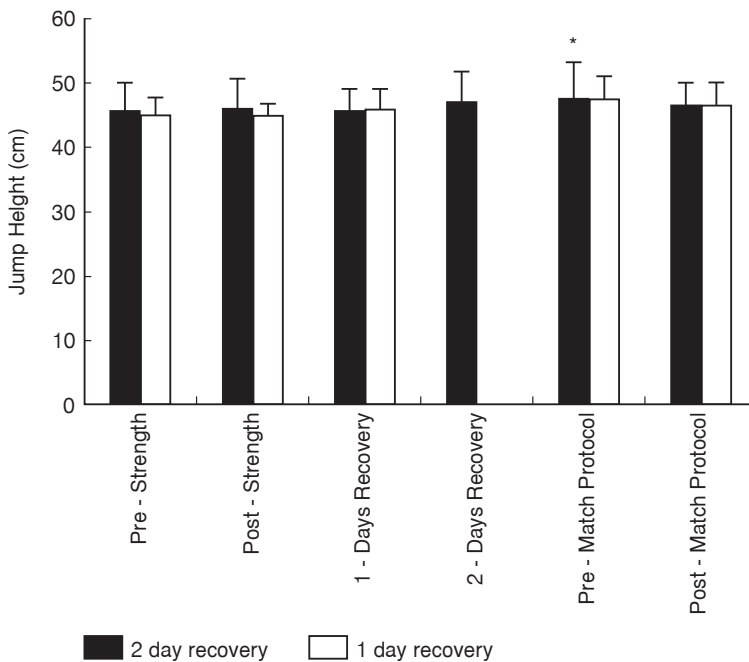


Figure 4: Vertical jump height (mean \pm s). * Significantly different from pre-strength exercise (excluding recovery days).

DISCUSSION

The principal aim of this investigation was to determine the impact of resistance exercise followed by either one or two day/s recovery on physiological variables that related to soccer performance. No significant difference was observed for all variables (MVIC, VJH, MS and MA). This suggests that the two experimental trials imposed a similar physiological strain on the subjects, irrespective of the number of recovery days. Intensive resistance exercise using heavy loads leads to a momentary decrease in muscle strength accompa-

nied by reductions in voluntary activation of the exercised muscles (15, 17, 26). The effect of the fatigue on the neuromuscular system is related not only to the intensity but also to the specific type of the using load, the recovery time and the type of muscle contractions (17, 29). In the current investigation, the resistance exercise which incorporated light loads and high intensity contractions produced no reduction in maximal isometric force and vertical jump height after the resistance training. In agreement with isometric force, muscle activation levels were recorded in excess of 96.64% throughout the course of the study and indicated that subjects were able to voluntarily activate their muscles at near maximal levels (33).

The impact of the recovery rate after the resistance training may give some advantages to estimate a proper strength training frequency. Consequently, in-season, high velocity/low load resistance training may take preference above heavy load (>80% 1RM) resistance training as it has been reported that muscle force is decreased 'several days' after the exercise bout with high load resistance training (8, 28). This decreased force is linked to (DOMS) occurring approximately 8 hrs after exercise and which peaks 2 to 3 days post-exercise (8, 9, 18). This study showed that muscle soreness was not significantly different between 1 day and 2 days of recovery ($p = 0.339$, $p > 0.05$). The significant main effect for time showed that the post-strength increase ($11.75 \text{ mm} \pm 4.45$) in muscle soreness returned towards pre-strength training levels prior to the pre-match simulation protocol.

Previous studies demonstrated prolonged training programmes which utilizes high contractions velocities with low loads improve muscle power and indicate superior results on variety performance variables (12, 16, 19, 34). These studies stressed the importance to evaluate the effectiveness of any training programme but they are limited in indicating the potential to negatively affect athletic performance in the short term if training sessions are scheduled too close to a competition.

In conclusion, the present study has indicated that high velocity/low load training is relatively non-fatiguing, produces little muscle soreness or reduction in central neuromuscular drive and can allow isometric muscle force and vertical jump height to be maintained to similar levels to those noted prior to its application following only 1 day of recovery.

REFERENCES

1. Almaasbakk B & Hoff J. Coordination, the determinant of velocity specificity. *Journal of Applied Physiology* 80: 2046-2052, 1996.
2. Askling C, Karlsson J and Thorstensson, A. Hamstring injury occurrence in elite soccer players after a preseason strength training with eccentric

- overload. *Scandinavian Journal of Medicine and Science in Sports* 13 (4): 244-250, 2003.
3. Atkinson G & Nevill AM. Statistical Methods for assessing measurements error (reliability) in variables relevant to sports medicine. *Sports Medicine* 26 (4): 217-238, 1998.
 4. Bangsbo J. The physiology of intermittent activity in football. In: *Science and Football III*. Eds: Reilly T, Bangsbo J and Hughes M. London, E & FN Spon. 43-53, 1997.
 5. Brzycki M. Strength testing-Predicting a one-rep max from reps-to-fatigue. *JOPERD* 68: 88-90, 1993.
 6. Byrne C, Twist C, and Eston R. Neuromuscular function after exercise-induced muscle damage. *Sports Medicine* 34 (1): 49-69, 2004.
 7. Chu DA. *Explosive Power and Strength*. Champaign, IL: Human Kinetics, 1996.
 8. Clarkson PM, Nosaka K and Braun B. Muscle function after exercise-induced muscle damage and rapid adaptation. *Medicine and Science in Sports and Exercise* 24 (5): 512-520, 1992.
 9. Connolly DAJ, SP Sayers and MP McHugh. Treatment and prevention of delayed onset muscle soreness. *Journal of Strength and Conditioning Research* 17: 197-298, 2003.
 10. Crewther B, Cronin J and Keogh J. Possible stimuli for strength and power adaptation. Acute mechanical responses. *Sports Medicine* 35 (11): 967-989, 2005.
 11. Drust B, Reilly T, and Cable NT . Metabolic and physiological responses to a laboratory based soccer-specific intermittent protocol on a non-motorised treadmill. In *Science and Football IV*, W. Spinks, T. Reilly & A. Murphy (Eds.), (pp. 217-225). Sydney: Routledge, London, 2002.
 12. Enoka RM. *Neuromuscular of human movement* 3rd ed. Champaign: Human Kinetics, 2002.
 13. Fleck SD and Kraemer WD. *Designing resistance training programs* 3d Edition, Champaign IL: Human Kinetics, 2004.
 14. Folland JP and Williams AG. The adaptations to strength training: Morphological and Neurological Contributions to increase strength. *Sports Medicine*, 37: 145-168, 2007.
 15. Hakkinen K, Pakarinen A, Alen M, Kauhanen H, Komi PV. Neuromuscular and hormonal responses in elite athletes to two successive strength training sessions in one day. *European Journal of Applied Physiology Occupational Physiology* 57: 133-139, 1998.
 16. Hakkinen, K. Neuromuscular and hormonal adaptations during strength and power training. *Journal of Sports Medicine* 29: 9-26, 1989.
 17. Hakkinen K. Neuromuscular fatigue and recovery in male and female athletes during heavy resistance exercise. *International Journal of Sports Medicine* 14: 53-59, 1993.

18. Hamling MJ & Quigley BM. Quadriceps concentric and eccentric exercise 2: Difference in muscle strength, fatigue and EMG activity in eccentrically-exercised sore and non-sore muscles. *Journal of Science and Medicine in Sport* 4: 104-115, 2001.
19. Harris GR, MH Stone, HS O'Bryant, CM Proulx and RL Johnson. Short term performance effects of high power, high force, or combined weight-training methods. *Journal of Strength and Conditioning Research*, 14: 14-20, 2002.
20. Hass CJ, Feigenbaum MS and Franklin BA. Prescription of resistance training for healthy populations. *Sports Medicine* 31 (14): 953-964, 2001.
21. Helgerud J, Kemi OJ, and Hoff J. Pre-season concurrent strength and endurance development in elite soccer players. In J. Hoff and J. Helgerud (Eds.), *Football (soccer): New developments in physical training research* (pp. 55-66). Trondheim, NTNU, 2003.
22. Hoff J & Helgerud J. Endurance and strength training for soccer players. *Sports Medicine*, 34: 165-180, 2004.
23. Hoff J. Training and testing physical capacities for elite soccer players. *Journal of Sports and Science* 23 (6): 573-582, 2005.
24. Kreamer WJ & Hakkinen K. *Strength training for sports (Handbook of sports Medicine and Science)*. Blackwell Science, 2002.
25. Koegh JW, Wilson GJ and Weatherby RP. A cross-sectional comparison of different resistance training techniques in the bench press. *Journal of Strength and Conditioning Research* 13: 247-258, 1999.
26. Komi PV, Rusko H. Quantitative evaluation of mechanical and electrical changes during fatigue loading of eccentric and concentric work. *Scandinavian Journal of Rehabilitation Medicine*. Supplement 3:121-126, 1974.
27. Komi PV. Stretch shortening cycle: a powerful model to study normal and fatigued muscle. *Journal of Biomechanics* 33: 1197-1206, 2000.
28. Leiger AB & Milner TE. Muscle function at the wrist after eccentric exercise. *Medicine and Science in Sports and Exercise* 33: 612-620, 2001.
29. Linnamo V, Hakkinen K, Komi PV. Neuromuscular fatigue and recovery in maximal compared to explosive strength loading. *European Journal of Applied Physiology Occupational Physiology* 77: 176-181, 1998.
30. Luis F. Aragón-Vargas. Evaluation of four vertical jump test: methodology, reliability, validity, and accuracy. *Measurement in Physical Education and Exercise Science* 4 (4): 215-228, 2000.
31. Merton PA. Voluntary strength and fatigue. *Journal of Physiology* 123 (3): 553-564, 1954.
32. Mohr M, Krustup P, and Bangsbo J. Match performance of high-standard soccer players with special reference to development of fatigue. *Journal of Sports Science* 21: 519-528, 2003.
33. Morton JP, Atkinson G, MacLaren DP, Cable NT, Gilbert G, Broome C, McArdle A, Drust B. Reliability of maximal muscle force and voluntary ac-

- tivation as markers of exercise-induced muscle damage. *European Journal of Applied Physiology* 94: 541-548, 2005.
34. Moss BM, Repsnes PE, Abildgaard A, Nicolaysen K and Jensen J. Effects of maximal effort strength training with different loads on dynamic strength, cross-sectional area, load-power and load velocity relationship. *European Journal of Applied Physiology* 75 (3): 193-199, 1997.
 35. Sale DG. Neural adaptations to strength training. In: Komi PV. Ed. *Strength and power in sport* (pp: 249-265) Oxford: Blackwell scientific publications, 1992.
 36. Schmidbleicher D. Training for power events. In P. Komi (Ed.), *Strength and power in sport* (pp: 381-395). Oxford: Blackwell. 1992.
 37. Wewers ME & Lowe NK. A critical review of visual analogue scales in the measurements of clinical phenomena. *Research in Nursing and Health* 13: 227-236, 1990.
 38. Wisloff U, Herlegud J and Hoff J. Strength and endurance of elite soccer players. *Medicine and Science in Sports and Exercise* 30: 462-467, 1998.
 39. Wisloff U, Costagna C, Herlegud J, Jones R and Hoff J. Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. *British Journal of Sports Medicine* 38: 285-288, 2004.
 40. Yap CW & Brown LE. Development of speed, agility and quickness for the female soccer athlete. *National Strength and Conditioning Association* 22 (1): 9-12, 2000.

Address for correspondence:

Kesoglou Ioannis
Webster Str., Henry Cotton Campus
L3 2ET. Liverpool
U.K
E-mail: i.kesoglou@yahoo.gr