THE ROLE OF EVALUATION THE QUADRICEPS TENDON TENSION IN THE MUSCULAR TRAINING OF SOCCER PLAYERS

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Abstract: Introduction. The explosive force represents a parameter that generates sports performance at soccer players. The key of the knee stability and the sport performance is obtain thru the muscular strength development and maintaining at the level of the knee extensors. The purpose of this research paper is to analyze the tension developed in the quadriceps tendon, bilaterally.
Materials and methods: The study included 23 subjects, average age of 11 years and 9 months, soccer players, 4 training sessions per week, analyzed the tension in the quadriceps tendon, bilaterally, all athletes are right-footed. The measurement was performed with the MCV sensor, made in Slovenia, fixed at the tendon level, and connected to the recording box of the tendon oscillations during the movement. The recorded data, expressed in newtons (N), was processed with the dedicated software of the MCV system.
Results: The average value recorded for the right knee was 0.087693N, and for the left knee it was 0.097361N. The analysis of these results shows that there is no significant difference between the values, even if the left limb is the supporting limb. This aspect signifies the existence, of a left-right muscular imbalance, which needs to be adjusted, given that obtaining sports performance from a technical point of view requires the development of explosive force.
Conclusions: The evaluation of the tension behavior at the level of the quadriceps tendon, provides important information regarding the load of the tendon level, the muscular imbalance and allows the design of a specific isoinertial type of training.
Keywords: *tendon, strength, isoinertial, soccer.*

Introduction

In a study by Miller et al. (Miller et al., 2009), analyzes performed using electromyography (EMG) shows that muscle activity during muscle activation by eccentric contractions (EC) is lower than during isometric or concentric contractions (CC); also, the perception of fatigue is generally lower after EC than after a combination of concentric and eccentric. Therefore, the special characteristics of EC have begun to be an important area of research, which seeks to increase the number of positive results of strength training as a method of protection against injury (Chiu & Salem, 2006). Previously, EC were excluded from training programs because they damaged muscles and caused inflammation to a greater extent than in the case of concentric contractions. However, a study by Tous et al. (Romero-Rodríguez & Tous-Fajardo, 2010) argue that this type of training increases the size, strength, and elasticity of muscle fiber, which makes the muscle-tendon structure respond favorably to eccentric contractions, having a protective effect on the tissue conjunctive; this plays an important role in improving strength sports activities, thus being successfully integrated into the training program for athletes, prevention and rehabilitation after sports injuries. (Romero-Rodríguez & Tous-Fajardo, 2010).

Isoinertial evaluation of eccentric muscle contraction

The two types are dynamic contractions consist of a concentric (shortening), eccentric (lengthening) or stretch-shortening cycle (a combination of the two types of contraction). (Komi & Bosco, 1978).

CC occur when the total tension developed in a muscle is sufficient to overcome any resistance to shortening. EC occur when the tension developed in the muscle is lower than the external resistance, the muscle elongating. (Hunter, 2000).

Differentiated physiological aspects of eccentric and concentric contractions

CC and EC differ in terms of neural, mechanical, and physiological parameters. It has been shown to generate greater forces during EC than during CC ones (Enoka, 1996; Jones & Round, 1990; Lindstedt, Lastayo & Reich, 2001). The order in which the motor units are required, the discharge rate, as well as their application threshold are different in the case of the two types of contractions (Enoka, 1996) which leads to the uniqueness of the neural commands that control eccentric contractions.

It is known that the electromechanical delay or the time elapsed between the biomechanical response and the actual installation of muscle tension, is shorter in the case of eccentric contractions compare to concentric ones (Cavanagh & Komi, 1979). Also, it has been shown that cortical activation (activity of the central nervous system) is higher, both in terms of amplitude and size of the area, in the case of maximum EC compared to CC ones.

This central nervous system additional activity during the maximal EC was considered necessary to build unique movement patterns, control more difficult movements, and limit the level of muscle activation to reduce the risk of injury. (Fang et al., 2004).

Eccentric contractions and sports performance

In sports, many movements require the exercise of high eccentric loads on the muscular system. For example, the hamstring muscles work eccentrically to decelerate the forward movement of the lower limb in the last stage of a running cycle. When the person sprints, the deceleration stage is shortened, requiring a greater eccentric muscle activation of the hamstring muscles to compensate for the advancing impulse of the leg. (Mirkov at al., 2004).

Regarding the vertical load of the quadriceps during the sprint, if the leg muscles oppose the descending impulse of the center of gravity (COM) during the sprint, then the increase and decrease of the COM will be less significant. The result is a lower vertical displacement of the COM in the case of a certain force and an impairment of the stiffness (force/displacement) of the running step, which in turn affects the ground contact time. Since speed is the product of length and frequency, the ability of the quadriceps to generate eccentric force would appear to have obvious advantages, especially in terms of step frequency (Mero, 1992). Changing the direction requires a decelerating motion and placing the foot on the ground to quickly impose a lateral force on the ground. To quickly change direction, the player must be able to counteract the lateral, horizontal, and vertical downward momentum of the COM by eccentric contractions of the extensor muscles of the leg. (Sheppard & Young, 2006).

Patterns of muscle activation during kicking in football matches

Kicking the ball is one of the most important skills a football player needs to pass and score (Luhtanen, 1988). Kicking the ball at high speed, important maneuver against the goalkeeper (Dorge et al., 1999) is obtained by momentum (Kawamoto et al., 2007). Kicking the soccer ball consists of 4 stages, as described by (Wickstrom, 1975; Anderson & Sidaway, 1994): 1. the swing stage in which the thigh and leg are withdrawn (Asami & Nolte, 1983), 2. the support stage, in which the hip-flexion starts, 3. the impact with the ball where the knee is extend and, 4. the final phase when the hip and knee are flexed. (Wickstrom, 1975).

Using the EMG evaluation some studies have attempted to explain patterns of muscle activation during the in-step kicks (Bollens & De Proft, 1987; Brophy et al., 2007; De Proft et al., 1988; Dorge et al., 1999; Kellis et al., 2004; McDonald, 2002; Orchard, 2002).

In these studies, kicking the soccer ball was considered to be the result of the simultaneous activity of numerous muscles, which connect certain segments and generate joint movements. Some of these muscles acted as antagonists during the blow and were thought to limit performance. Previous studies that have addressed this phenomenon have called it a "*football paradox*" (Bollens & De Proft, 1987; Bollens, De Proft, & Clarys, 1987; Clarys, et al., 1984; De Proft et al., 1988).

In short, the more intense the simultaneous activity of these antagonistic muscles, the smaller the net impulse bound to that joint will be and the less efficient the resulting segmentation action will be (Kellis & Katis, 2007).

Therefore, the activity of agonist and antagonist muscles directly affects the quality of the shot, although some researchers (De Proftet al. 1988; Dorge et al., 1999). Studies showed that both categories of muscles (agonists and antagonists) when the experienced players is hitting the ball a higher level of agonistic activation is produce (Bollens & De Proft, 1987; De Proft et al., 1988), but the differences in muscle activation between professional and amateur footballers were not clearly explained.

Asami and Nolte (Asami & Nolte, 1983) reported that the relationship between the speed of the ball and the force of the knee extensor of the foot kicking the ball depends on the player's experience, and suggested that the muscle strength of the knee extensor influences less the speed of the ball in the case of more experienced players. (Asami & Nolte, 1983).

The knee (VL and VM) and ankle (GAS - gastrocnemius) extensors initially provide support by eccentric flexion, while the subsequent concentric extension provides the vertical propulsion needed to move on to the next movement. During this period the reaction force existed, but it was low, because, being a hip extensor, if this force had been higher, it would have prevented the extension of the hip. Its function is complex, but as the hip extends, the reaction force would probably help to extend the knee.

The effort produced by the muscles at this stage is important because it determines the characteristics of the step (for example its length) and the position of the foot with which it does not hit the ball.

When the kicking leg is lifted off the ground (approximately −200 ms) at the beginning of the balance stage there is a significant reduction in muscle activity. Muscle activity initially contributes to hip flexion and then (approximately −150 ms) to knee extension, due to intense activity at the knee extensors (VL and VM). Blood flow and GAS remained low, because they are flexor muscles in the knee, and in this case, an intense activity would inhibit their extension movement. The muscle activity required for the actual impact in the knee extensors remains intense during the actual impact, then decreases rapidly after it occurs. In this phase, the activity of blood flow, and especially of GAS, also increased. Both help to flex the knee, which is an essential component of the completion stage. (Lees et al., 2009).

This research aims to perform a muscular evaluation of the strength in the patellar tendon, based on which could be propose a training program based on the isoinertial principle, this being a fact-finding study.

For this, the main aim of this research is to analyse the patellar tendon tension development during the shot at goal and identify the difference between left and right lower limb, behaviour.

Materials and methods

Subjects. The study included 13 subjects, with a mean age of 11 years and 9 months, soccer players. We made the assessment of the tension developed in the quadriceps-patellar tendon, bilaterally, given that all athletes are right-footed. Its measurement was performed with the MCV sensor (Fig.1 and Fig. 2), made in Slovenia, fixed at the tendon level, and connected to the recording box of tendon oscillations in knee extension movement, during shot at goal. The recorded data, expressed in newtons (N), were processed with the dedicated software of the MCV system.

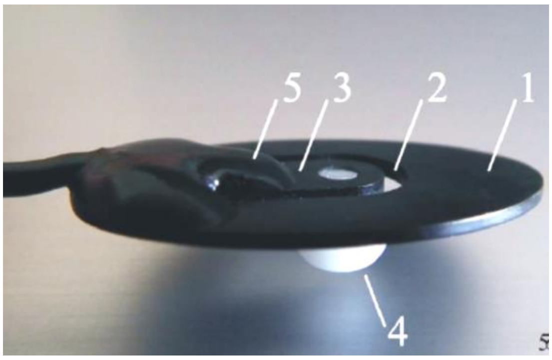

Figure 1. - MC sensor (1): laminate; (2): incision; (3): tonguelet; (4): sensor tip; (5): strain gauge.

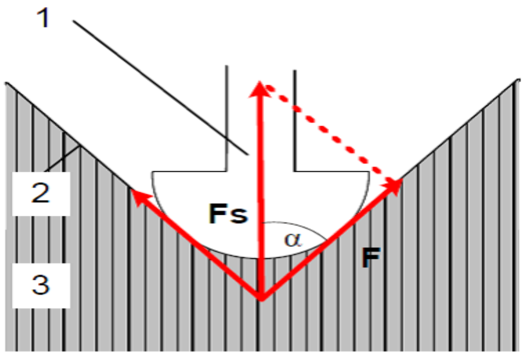

Figure 2. A simplified representation of the MC measuring principle for the determination of the mechanical and physiological properties of skeletal muscles (1): sensor tip; (2): skin and intermediate layer; (3): measured muscle.

Results

Measurement results with The MCV sensor at junior soccer players are presented in Table 1. The results of the initial assessment of the tension developed in the quadriceps - patellar tendon, bilaterally, during the knee extension movement during shot at goal. The results are presentaed in the next figures – Figures no. 1-13.

Table 1. The maximum value of the tension measured in the patellar tendon for the "shot at goal", with the right foot

Subjects	**Age**	**Weight (Kg)**	**Maxim tension quadriceps(right) SCV (N)**	**Mexim tension quadriceps(left) SCV(N)**
S1	11 years 11 months	48	0.103028	0.053979
S2	12 years 3 months	50	0.048198	0.113599
S3	12 years 7 months	50	0.062842	0.079761
S4	11 years 11 months	48	0.100044	0.107959
S5	12 years 7 months	45	0.082368	0.094263
S6	11 years 11 months	46	0.100995	0.069952
S7	12 years 6 months	50	0.109521	0.051562
S8	11 years 10 months	43	0.093457	0.100044
S9	12 years 6 months	35	0.106489	0.062036
S10	12 years 2 months	42	0.067675	0.105542
S11	12 years 2 months	63	0.040142	0.108384
S12	11 years 11 months	44	0.052085	0.107959
S13	12 years 7 months	40	0.06417	0.090659
Media	**11 years 9.5 months**	**46.167**	**0.079309**	**0.088131**
std.dev.	**0.725**	**6.846**	**0.023538**	**0.021338**
Coef var		**14.82877**	**29.67927**	**24.21229**

Graphical variation of the tension measured on the patellar tendon at both feet, during the execution of the shot at the goal with the right foot

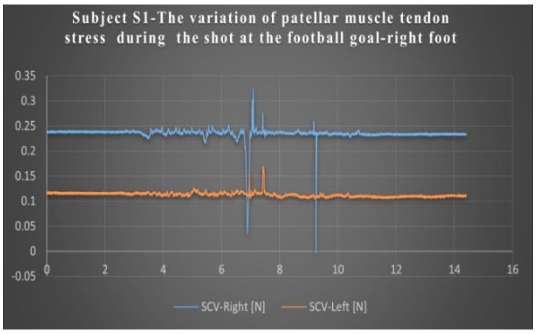

Fig 1. Subject S1-The variation of patellar muscle-tendon stress during the shot at the goal-right foot

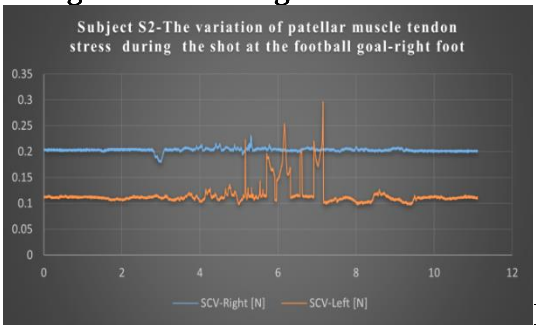

Fig 2. Subject S2-The variation of patellar muscle-tendon stress during the shot at the goal-right foot

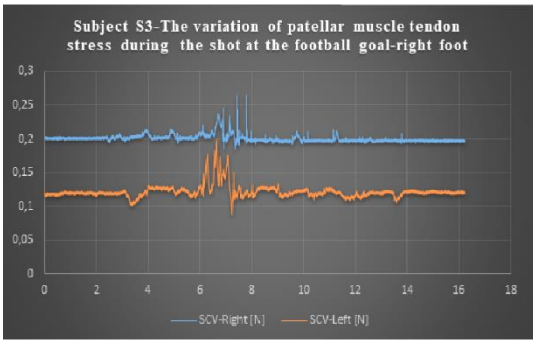

Fig 3. Subject S3-The variation of patellar muscle-tendon stress during the shot at the goal-right foot

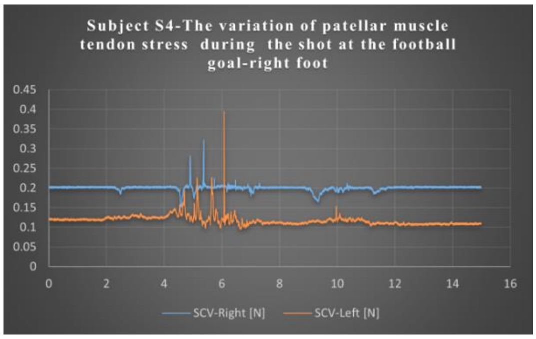

Fig 4. Subject S4-The variation of patellar muscle-tendon stress during the shot at the goal-right foot

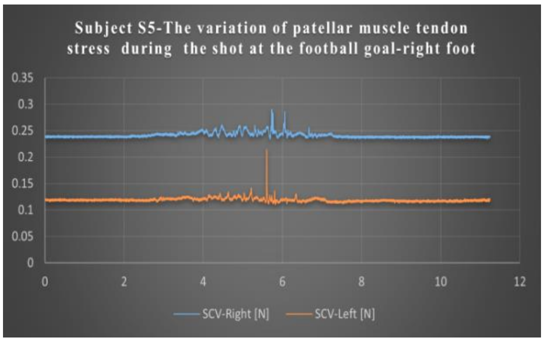

Fig 5. Subject S5-The variation of patellar muscle-tendon stress during the shot at the goal-right foot

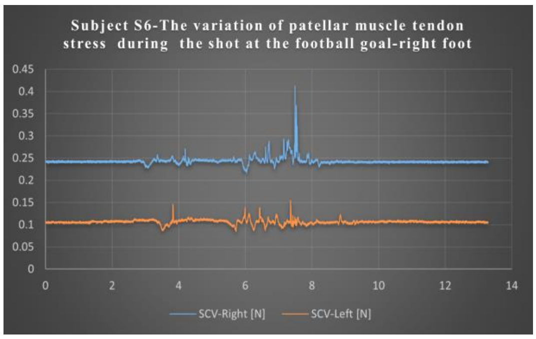

Fig 6. Subject S6-The variation of patellar muscle-tendon stress during the shot at the goal-right foot

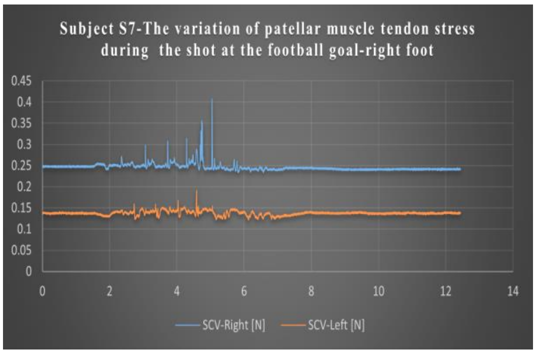

Fig 7. Subject S7-The variation of patellar muscle-tendon stress during the shot at the goal-right foot

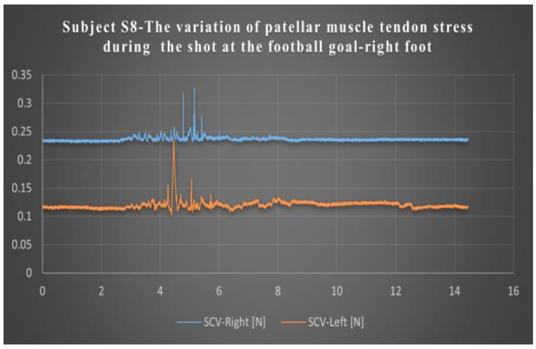

Fig 8. Subject S8-The variation of patellar muscle-tendon stress during the shot at the goal-right foot

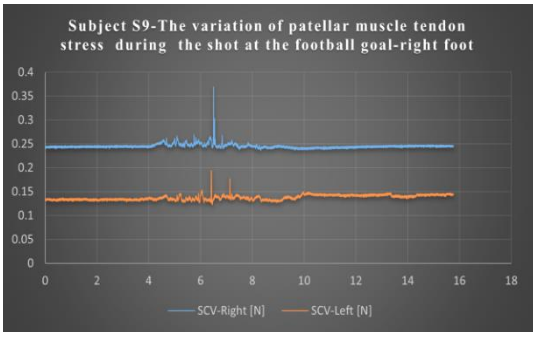

Fig 9. Subject S9-The variation of patellar muscle-tendon stress during the shot at the goal-right foot

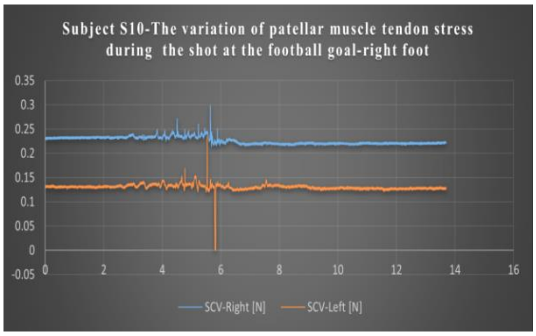

Fig 10. Subject S10-The variation of patellar muscle-tendon stress during the shot at the goal-right foot

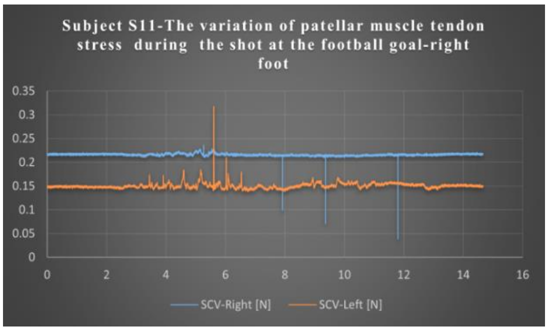

Fig 11. Subject S11-The variation of patellar muscle-tendon stress during the shot at the goal-right foot

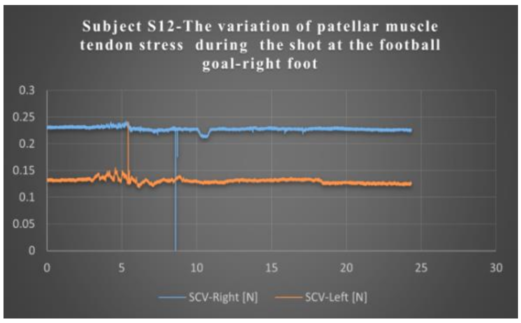

Fig 12. Subject S12-The variation of patellar muscle-tendon stress during the shot at the goal-right foot

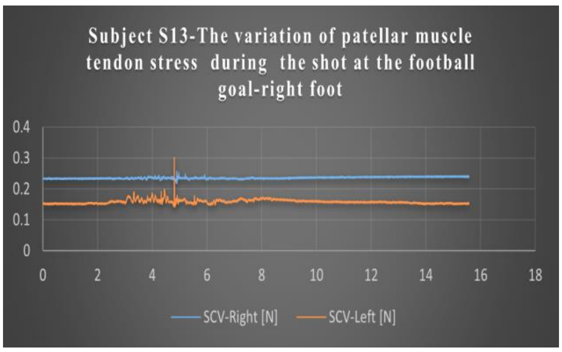

Fig. 13. Subject S13-The variation of patellar muscle-tendon stress during the shot at the goal-right foot

The average value of the tendon tension, recorded for the right knee was 0.087693N, and for the left knee, it was 0.097361. The analysis of the graphics indicates the existence of a muscular behavior similar to the thigh muscles, bilaterally, with minimum tension values between 0.1N - 0.25N, in most athletes.

It can be observed that at subjects S2 (Fig.2), S10(Fig.10), S11(Fig.11), S12(Fig.12) and S13(Fig.13) are high oscillations to left lower knee then right knee, where we can see minimal oscillations. This aspect means a minimal explosive force for right lower limb during the shot at the goal. Subjects S1,S3,S4,S5,S6,S7,S8,S9 present close oscillations for rigth and left side.

Statistical analysis Student t test for equal dispersions, for Table 1 values, we obtain p=0,345 which is up to significance value choice by us, which is α=0.05 (we propose the probability 95%).

In this case null hypothesis could be accepted, for tension in patellar tendon and are not significant difference between left and right side.These results mean a functional bilateral symmetry (left/right) but also a decrease of explosive force for quadriceps muscle, much more stressed to right knee. For this reason we porpose to develop a muscle training based on isoinertial technic, for increase the explosive muscle force, especially ofr right side. in addition for left knee the muscle training needs to be increase for improve the knee stability.

Discussions

Data analysis in the context of the analysis of the soccer game shows that all-important activities in football are performed at high speeds, football players perform sprints every 90 seconds that can last 2-4 seconds and cover up to 11% of the distance traveled during a match. (Reilly& Thomas, 1976; Donoghue, 2001). These data can be correlated with the fact that from an isokinetic point of view, the movement at the knee level reaches 600-700˚/s during high-intesity efforts, such as sprinting. (Sale, 1992). Soccers make about 50 quick and strong turns to maintain balance and control of the ball under opposing defensive pressure. Therefore, coaches are likely to consider high-speed football training when designing training programs to improve the explosive power of players. (Prevost et al., 1999). An important goal of training would be to reduce the imbalance from left to right, which can be achieved through specific isoinertial training. This could be beneficial for soccer players to improve performance and, most importantly, reduce the risk of injury to the lower limbs. A bilateral imbalance of the hamstring and quadriceps muscles between the dominant and opposite lower limb was 10% in soccer and it has been reported by other authors (Hamzeh& Head, 2004). A muscle imbalance of more than 10% between the two lower limbs could increase the risk of injury (Kramer & Balsor, 1990).

Previous studies have argued that changes in explosive force could be the result of learning (Rutherford &Jones, 1986) better coordination (Sale, 1992), and reduced antagonistic co-contraction. (Wisloff, Helgerud &Hoff, 1998).

Proposals for designing an isoinertial training based on the tendon determinations in the tendons of the muscle groups predominantly involved in performing the shot at goal can generate changes in the production of high angular velocity during the specific soccer training of 24 weeks and would be based on increases significant effects of neuromuscular adaptation through training. Such developments were supported by the observation of EMG registration which showed an increase in muscle electrical activity primarily at training speed. Specifically, it seems that speed of movement, controlled by loading, plays a key role in improving speed performance and possible neural adaptation (Häkkinen, Komi &Alen, 1985).

The findings of previous research have supported the idea of neuromuscular adaptation as a result of a specific training regimen. For example, Behm and Sale (1993) argued that high-speed training could involve significant neuromuscular adaptations.

Häkkinen et al. (1985) showed significant improvements in strength and power in light resistance explosive force training. Such developments were supported by the observation of electromyography which showed an increase in muscle electrical activity primarily at training speed. Specifically, it seems that movement speed, controlled by

loading, plays a key role in improving speed performance and possible neuromuscular adaptation. (Häkkinen, Komi &Alen, 1985).
Prevost et al. (1999) reported short-term improvements in isokinetic torque at high speeds after training involving rapid isokinetic contractions, which may occur due to neuronal facilitation. (Prevost, Nelson & Maraj, 1999).

Conclusions

The evaluation of the patellar tendon tension behavior provides important information regarding the load produced at the level of the tendon, the muscular imbalance, and allows the design of a specific isoinertial type training. The conclusions of these results reflect the presence small muscle imbalance, left-right, in the knee and a less explosive muscle force at right side. All of these informations obtained after the evaluation requires a deeper quantification, also for the antagonistic muscles, in the sense of ongoing a muscle training program to strengthen the explosive force, and reduce the risk of injury.

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References

Anderson, D. I., & Sidaway, B. (1994). Coordination changes associated with practice of a soccer kick. *Research quarterly for exercise and sport*, *65*(2), 93–99. https://doi.org/10.1080/02701367.1994.10607603

Asami, T., Nolte, V. (1983). Analysis of powerful ball kickin. Biomechanics VIII-B, H. Matsui and K. Kobayashi, eds, Champaign Illinois: Human Kinetics, 695–700.

Behm, D. G., & Sale, D. G. (1993). Velocity specificity of resistance training. *Sports medicine (Auckland, N.Z.)*, *15*(6), 374–388. https://doi.org/10.2165/00007256-199315060-00003.

Bollens, E., De Proft E. (1987). The accuracy and muscle monitoring in soccer kicking. Biomechanics X-A, B. Jonsson, ed., Champaign Illinois: Human Kinetics, 283– 288.

Bollens, E., De Proft, E., Clarys, J. (1987). The accuracy and muscle monitoring in soccer kicking. Biomechanics X-A, B. Jons son, ed., Champaign Illinois: Human Kinetics, 283– 288.

Brophy, R. H., Backus, S. I., Pansy, B. S., Lyman, S., & Williams, R. J. (2007). Lower extremity muscle activation and alignment during the soccer instep and side-foot kicks. *The Journal of orthopaedic and sports physical therapy*, *37*(5), 260–268. https://doi.org/10.2519/jospt.2007.2255

Cavanagh, P. R., & Komi, P. V. (1979). Electromechanical delay in human skeletal muscle under concentric and eccentric contractions. *European journal of applied physiology and occupational physiology*, *42*(3), 159–163. https://doi.org/10.1007/BF00431022

Chiu, L. Z., & Salem, G. J. (2006). Comparison of joint kinetics during free weight and flywheel resistance exercise. *Journal of strength and conditioning research*, *20*(3), 555–562. https://doi.org/10.1519/R-18245.1

Clarys, J.P., Dufour, W., Pynaert, M. (1984). Electromyography of three soccer kick movements. Geneeskunde en Sport 17, 17-21.

De Proft, E., Cabri, J., Dufour, W., Clarys, J.P. (1988). Strength training and kick performance in soccer players. Reilly T, Lees A, Davids K, Murphy WJ, eds. Science and football II. London E & FN Spon, 108-113.

De Proft, E., Clarys, J., Bollens, E., Cabri J., Dufour, W. (1988). Muscle activity in the soccer kick. Science and Football, T. Reilly, A. Lees, K. Davids and W.J. Murphy, eds, London E & FN Spon, 434–440.

Dörge, H. C., Andersen, T. B., Sørensen, H., Simonsen, E. B., Aagaard, H., Dyhre-Poulsen, P., & Klausen, K. (1999). EMG activity of the iliopsoas muscle and leg kinetics during the soccer place kick. *Scandinavian journal of medicine & science in sports*, *9*(4), 195–200. https://doi.org/10.1111/j.1600-0838.1999.tb00233.x

Enoka R. M. (1996). Eccentric contractions require unique activation strategies by the nervous system. *Journal of applied physiology (Bethesda, Md.: 1985)*, *81*(6), 2339–2346. https://doi.org/10.1152/jappl.1996.81.6.2339

Fang, Y., Siemionow, V., Sahgal, V., Xiong, F., & Yue, G. H. (2004). Distinct brain activation patterns for human maximal voluntary eccentric and concentric muscle actions. *Brain research*, *1023*(2), 200–212. https://doi.org/10.1016/j.brainres.2004.07.035

Häkkinen, K., Komi, P. V., & Alén, M. (1985). Effect of explosive type strength training on isometric force- and relaxation-time, electromyographic and muscle fibre characteristics of leg extensor muscles. *Acta physiologica Scandinavica*, *125*(4), 587–600. https://doi.org/10.1111/j.1748-1716.1985.tb07759.x

Hamzeh, M., Head, A. (2004). Isokinetic hamstrings and quadriceps evaluation of professional soccer players. Sports Sci, 22(3):265-266.

Hunter, G. (2000). Muscle physiology. In: Essentials of Strength Training and Conditioning. Baechle TR, Earle RW, eds. Champaign, IL: Human Kinetics, Baechle TR, Earle RW, eds. Champaign, IL: Human Kinetics, 3-13.

Jones, D.A., Round, J.M. (1990). Skeletal Muscle in Health and Disease. Manchester: Manchester University Press.

Kawamoto, R., Miyagi, O., Ohashi, J., & Fukashiro, S. (2007). Kinetic comparison of a side-foot soccer kick between experienced and inexperienced players. *Sports biomechanics*, *6*(2), 187–198. https://doi.org/10.1080/14763140701324966

Kellis, E., & Katis, A. (2007). Biomechanical characteristics and determinants of instep soccer kick. *Journal of sports science & medicine*, *6*(2), 154–165.

Kellis, E., Katis, A., & Gissis, I. (2004). Knee biomechanics of the support leg in soccer kicks from three angles of approach. *Medicine and science in sports and exercise*, *36*(6), 1017–1028. https://doi.org/10.1249/01.mss.0000128147.01979.31

Kramer, J. F., & Balsor, B. E. (1990). Lower extremity preference and knee extensor torques in intercollegiate soccer players. *Canadian journal of sport sciences = Journal canadien des sciences du sport*, *15*(3), 180–184.

Lees, A., Steward, I., Rahnama, N., Barton, G. (2009). Understanding lower limb function in the performance of the maximal instep kick in soccer. Proceedings of the 6th International Conference on Sport, Leisure and Ergonomics T. Reilly and G. Atkinson, eds, London: Routledge, 149–160.

Lindstedt, S. L., LaStayo, P. C., & Reich, T. E. (2001). When active muscles lengthen: properties and consequences of eccentric contractions. *News in physiological sciences: an international journal of physiology produced jointly by the International Union of Physiological Sciences and the American Physiological Society*, *16*, 256–261. https://doi.org/10.1152/physiologyonline.2001.16.6.256

Luhtanen, P. (1988). Kinematics and kinetics of maximal instep kicking in junior soccer players. Science and Football, T. Reilly, A. Lees, K Davids and W.J. Murphy, eds, London: E&FN Spon,, 441-448.

McDonald, M. (2002). Relative timing of EMG profiles for novice and elite soccer players. Science and Football IV, W. Sprinks, T. Reilly and A. Murphy, eds, London: Routledge, 22-26.

Mero, A., Komi, P. V., & Gregor, R. J. (1992). Biomechanics of sprint running. A review. *Sports medicine (Auckland, N.Z.)*, *13*(6), 376–392. https://doi.org/10.2165/00007256-199213060-00002

Miller, P. C., Hall, E. E., Chmelo, E. A., Morrison, J. M., DeWitt, R. E., & Kostura, C. M. (2009). The influence of muscle action on heart rate, RPE, and affective responses after upper-body resistance exercise. *Journal of strength and conditioning research*, *23*(2), 366–372. https://doi.org/10.1519/JSC.0b013e31818548f6

Mirkov, D. M., Nedeljkovic, A., Milanovic, S., & Jaric, S. (2004). Muscle strength testing: evaluation of tests of explosive force production. *European journal of applied physiology*, *91*(2-3), 147–154. https://doi.org/10.1007/s00421-003-0946-8

O Donoghue, P. (2001). Time-motion analysis of work-rate in elite soccer. Tavares MF, ed. Notational analysis of sport IV: Centre for Team Sports Studies. Porto: Faculty of Sport Sciences and Physical Education, 65-70.

Orchard, J. W. (2002). Muscle activity during the drop punt kick. in: Science and Football

IV, W. Sprinks, T. Reilly and A. Murphy, eds, London: Taylor and Francis, 32-43.

Prevost, M. C., Nelson, A. G., & Maraj, B. K. (1999). The effect of two days of velocity-specific isokinetic training on torque production. *The Journal of Strength & Conditioning Research*, *13*(1), 35-39.

Reilly, T. (1976). A motion analysis of work-rate in different positional roles in professional football match-play. *J Human Movement Studies*, *2*, 87-97.

Romero-Rodríguez, ***DE***., Tous-Fajardo, J. (2010). Prevención de lesiones en el deporte. Claves para un rendimiento óptimo. Injury prevention in sports. Keys to optimal performance. Madrid: Editorial Panamericana. Madrid: Editorial Panamericana.

Rutherford, O. M., & Jones, D. A. (1986). The role of learning and coordination in strength training. *European journal of applied physiology and occupational physiology*, *55*(1), 100–105. https://doi.org/10.1007/BF00422902

Sale, D., Quinlan, J., Marsh, E., McComas, A.J. & Belanger, A.Y. (1982) Influence of joint position on ankle plantarflexion in humans. Journal of Applied Physiology 52(6), 1636–1642.

Sheppard, J. M., & Young, W. B. (2006). Agility literature review: Classifications, training and testing. *Journal of sports sciences*, *24*(9), 919-932. doi:https://doi.org/10.1080/02640410500457109

Wickstrom, R. L. (1975). Developmental kinesiology: Maturation of basic motor patterns. *Exercise and sport sciences reviews*, *3*(1), 163-192.

Wisløff, U., Helgerud, J., & Hoff, J. (1998). Strength and endurance of elite soccer players. *Medicine and science in sports and exercise*, *30*(3), 462–467. https://doi.org/10.1097/00005768-199803000-00019