REVIEW ARTICLE

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Isoinertial technology for rehabilitation and prevention of muscle injuries of soccer players: literature review

Tecnología isoinercial para la rehabilitación y prevención de lesiones musculares en futbolistas: revisión de la literatura

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| Abstract |

Introduction: Soccer is the sport with the highest risk of muscle injury for players. Eccentric exercise is fundamental for reducing injury rates and isoinertial technology devices cause an increase in eccentric demands after a concentric contraction.

Objective: To identify the use of isoinertial technology in the fields of physical activity and sports for rehabilitation and prevention of muscle injuries reported in scientific literature.

Materials and methods: A search of scientific papers in PubMed, Google Scholar, EMBASE and Science Direct data base was performed by using the following MeSH medical terms and search equations: [isoinertial AND technology AND flywheels] and [free weight AND sport AND humans AND soccer].

Results: 23 references, classified into three approaches, were selected: isoinertial technology for rehabilitation, fitness and injury prevention. The use of this technology is fundamental due to the increase of the eccentric demand in muscle groups.

Conclusions: Isoinertial technology is a useful tool for treating and preventing injuries, as well as for the development of physical qualities. However, it is necessary to work on protocols that allow unifying its usage parameters so that it can be included in prevention programs.

Keywords: Injuries; Athletes; Prevention; Exercise; Soccer (MeSH).

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| Resumen |

Introducción. El fútbol presenta el mayor riesgo de lesión muscular en la práctica deportiva. El ejercicio excéntrico es clave en la reducción de las tasas de lesiones donde los dispositivos con tecnología isoinercial generan un aumento en las demandas excéntricas.

Objetivo. Identificar el uso de la tecnología isoinercial en el ámbito de la actividad física y el deporte para la rehabilitación y prevención de lesiones musculares reportadas en la literatura científica.

Materiales y métodos. Se realizó una búsqueda de artículos científicos en las bases de datos PubMed, Google Scholar, EMBASE y Science Direct utilizando los términos MeSH y las ecuaciones de búsqueda [isoinertial AND technology AND flywheels] y [free weight And sport And humans and soccer].

Resultados. Se seleccionaron 23 referencias, las cuales fueron clasificadas en tres enfoques: tecnología isoinercial en rehabilitación, en condición física y en prevención de lesiones. El uso de esta tecnología es fundamental por el aumento en la carga excéntrica en los grupos musculares.

Conclusiones. La tecnología isoinercial es una herramienta útil para el tratamiento de lesiones, su prevención y el desarrollo de cualidades físicas; sin embargo, es necesario que para su inclusión dentro de los programas de prevención se construyan protocolos que permitan unificar los parámetros de uso.

Palabras clave: Traumatismos en atletas; Rehabilitación; Ejercicio; Fútbol (DeCS).

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Introduction

Compared to other team sports, soccer has the highest risk of injury; 70% of them are located in the lower extremities and muscle injuries are the most frequent (1). Ekstrand (2) states that 92% of

muscle injuries affect the four major muscle groups of the lower limbs: hamstring (37%), adductors (23%), quadriceps (19%) and calf muscles (13%). 16% of muscle injuries reported are repeated injuries, which cause longer absences. In particular, and because of its two-joint design, hamstring and quadriceps rectus femoris present a significant risk of injury during rapid movements, that is, sprint, stopping, acceleration, change of direction, kicking, landing, etc.

According to Jesper *et al.* (3), the incidence of hamstring injuries is 0.5 to 1.5 injuries per 1 000 hours of exposure during matches and trainings. Besides the high incidence, a common problem related to this injury is the risk of recurrence; the rate reported is 22% of players in the first two months after the injury.

Woods *et al.* (4) state that rectus femoris injuries are frequent in professional soccer, especially during the preseason. Barcelona Club reports that strain injuries in this muscle had an incidence of 6% in 2009. However, due to the shortage of literature on this type of injury, little is known about risk factors, time lost or recurrence rates (5).

These injuries are a serious danger to athletes because they cause long absences from training and competitions, affect their quality of life and generate enormous costs for teams and players (2). Regarding this issue, Gianotti & Hume (6) report the cost-effectiveness of sports injuries and protection elements prevention programs, highlighting cost reduction by using appropriate sports equipment and prevention programs that include balance and proprioceptive exercises.

Apart from considering costs, location and prevalence, it is essential to determine the risk factors that favor the lesion in order to address the issue of prevention of injury among soccer players (7,8).

Muscle injuries can occur due to the interaction of several factors, including intrinsic-internal and extrinsic-external factors. The former refers specifically to athlete factors that may be modifiable and non-modifiable; non-modifiable internal factors include age, since risk of injury increases over time, and gender, since women have higher risk of injury due to increased knee valgus.

The internal modifiable factors include previous history of similar injuries (previous injuries is the main risk factor for a new one) and physical conditions determined by the development of physical skills such as flexibility, aerobic capacity, strength and speed (2,9). Scientific literature establishes that muscle imbalance caused by strength deficit is the second most important factor of risk, because muscle or strength imbalance between agonists and antagonists, that is, between the tendons of the hamstring and quadriceps and/or lack of strength of the bilateral hamstring, is one of the most common factors (7,10,13).

According to Tais (14), further development of muscle strength occurs when an external force is greater than that produced by the muscle and it stretches while maintaining the contraction, thus creating a negative work called eccentric contraction. It has been suggested that eccentric exercise can reduce injury rates because muscle strain injuries occur when activated muscles lengthen over optimal lengths; therefore, injuries can be reduced, if the optimal length can be increased. Studies have shown that this length increases consistently due to eccentric exercise (15).

Authors like McHugh *et al.* (16,17) conducted a study to establish the adaptations generated in the muscle through eccentric exercise, which found that there are neural, mechanical and cellular adaptations. Meanwhile, Nosaka & Aoki (18) stated that, due to neural adaptations, recruitment of motor units is improved, motor unit trigger synchrony increases and a better load distribution between the fibers occurs. Other studies by Nosaka *et al.* (19) and Souza & Paz (20) state that eccentric training substantially increases muscular strength when the skeletal muscle lengthens at higher speeds, that is, with eccentric contractions, so that the production of strength is five times greater in the eccentric muscle actions compared to exercises that generate concentric contractions (19).

Regardless the size of the muscle mass of the tissues involved and despite a greater force production during muscle lengthening, eccentric exercise has a metabolic cost lower than concentric contractions. According to Roig *et al.*, eccentric contractions during low utilization of ATP (adenosine triphosphate) and a reduced concentration of metabolites such as ammonium and lactate (21) is generated.

In a study by Miller *et al.* (22), an analysis made using electromyography (EMG) shows that muscle activity during muscle actions with eccentric contractions is lower than during isometric or concentric contractions; also, the perception of fatigue is generally lower after eccentric exercise than after combining the concentric/eccentric exercise (22). Therefore, the special characteristics of eccentric actions are becoming an important research field, in which attempts to increase positive results of strength training as a protective method against injuries are sought (23).

Previously, the eccentric exercise had been excluded from training programs because such work produces greater damage and muscle inflammation compared to concentric work. Nevertheless, a review by Tous *et al.* (24) states that this type of training increases the size, strength and spring quality of the muscle fiber, so muscle-tendon structure responds favorably to eccentric exercise with a protective effect in the connective tissue; this plays an important role in improving high power sports activities, so it has been successfully incorporated into athletic performance, health, prevention and rehabilitation of sports injuries programs (24).

Thus, isoinertial technology devices become important tools for preventing injuries by allowing the increase of demands of eccentric action after a concentric action because of the inertial load caused during the return movement. Although these machines are isoinertial trends in the field of strength training (25), they are not used frequently in injury prevention programs and have little scientific evidence proven in research. That is why it is necessary to conduct a review to identify the use of isoinertial technology from the scientific literature.

Isoinertial technology

This type of technology can be considered one of the latest trends, as well as a pioneer in strength training. The increase of the eccentric demand produced through isoinertial technology is based on the use of wheels to provide independent inertial resistance to gravity (26).

This technology uses the inertia of a wheel instead of the potential energy obtained by the position of an external object. In the concentric phase, the individual generates kinetic energy through the rotation of the wheel, which is braked during the eccentric phase, where increased recruitment of motor units is required to stop the inertia of the wheel during the return movement.

In this system, resistance force is dynamic and proportional to that generated by the subject. Several studies conducted with isoinertial technology have shown that it enables the development of forces similar or superior to the same exercise done with traditional weights. This technology is currently being used with excellent results in the areas of training, rehabilitation and retraining (27,28).

Although this methodology is not new, interest in eccentric work has led to a more pronounced use of this technology in the

last decade, highlighting the use of machines as the yo-yo and the conical pulleys (27). It is important to stress the work with versapulley isoinertial machines when it comes to obtaining not only eccentric overload, but simulation of the movement in the three dimensions of space, as in the sport event, which does not occur during trainings with conventional overload.

The versapulley isoinertial machines (conical pulley) and the yo-yo develop strength/power and allow generating concretic, eccentric and plyometrics workout, causing a high rate of development of explosive strength and load deceleration required for all multidirectional sports (28,29). The differences between the two training systems is that, while the versapulley allows the development of high eccentric speed with moderate to high strength levels, the YoYo Technology™ enables the development of high levels of force with moderate to low speeds. Therefore, both training systems are necessary and complementary to completely cover the spectrum of force-velocity (27).

Materials and methods

An exploratory-descriptive study was conducted in two phases: the first consisted of a review of the literature and the second in its classification and analysis.

Literature review

A search of scientific literature was performed by consulting the PubMed, Google Scholar, EMBASE and Science Direct databases. The search was conducted between February and December 2014, taking into account the Medical Subject Headings (MESH) and search equations [Isoinertial AND technology AND flywheels] and [Free weight AND sport and humans AND soccer].

Inclusion criteria

The criteria for study inclusion were: papers related to isoinertial technology published between 1998 and 2014 —considering that the first study performed using isoinertial technology was published in 1998—, review articles, cohort and cross-sectional studies, and controlled and uncontrolled clinical trials available in full text.

For the selection of papers, a bibliometric analysis, which allowed defining and applying filters by title and abstract to determine the items to be reviewed in full text, was made.

Classification and analysis of studies

Systematization was conducted through a matrix describing the characteristics and contributions of each paper to the research objective. Such matrix allowed to classify the papers according to the topics addressed —isoinertial technology in rehabilitation, isoinertial technology in fitness and isoinertial technology in injury prevention— to perform content analysis afterwards.

Results

In the four analyzed databases, 64 references related to the topic of isoinertial technology were found with access to full text documents, of which 23 that met the inclusion criteria set forth above were selected after performing a detailed review by two researchers, of both title and abstract (Figure 1).

In a second phase, the 23 references based on three approaches were distributed as follows: isoinertial technology rehabilitation (nine papers), isoinertial technology in fitness (ten papers) and isoinertial technology in injury prevention (four papers) (Table 1).

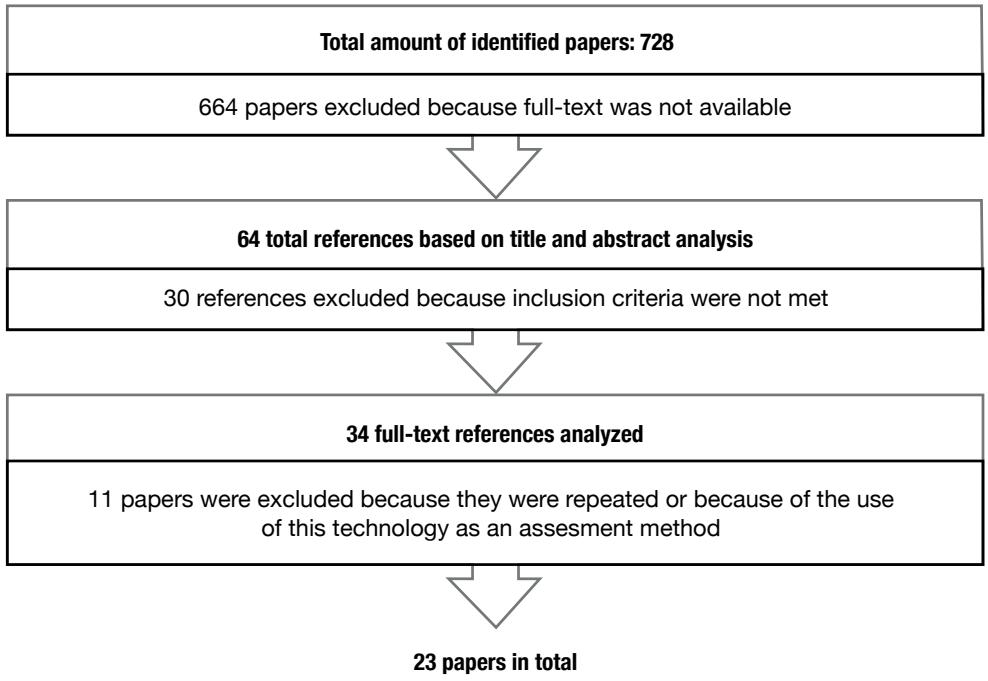

Figure 1. Flow chart of included papers. Source: Own elaboration based on the data obtained in the study.

Table 1. Paper analysis matrix.

Category	Author	Paper	Publication	Year
Isoinertial technology in rehabilitation	Romero-Rodríguez D, Gual D, Tesch PA.	Efficacy of an inertial resistance training paradigm in the treatment of patellar tendinopathy in athletes: A case-series study	Physical Therapy in Sport	2011
	Smith SM, Zwart SR, Heer M, Lee SM, Baecker N, Meuche S, Macias BR, Shackelford LC, Schneider S, Hargens AR.	WISE-2005: Supine treadmill exercise within lower body negative pressure and flywheel resistive exercise as a countermeasure to bed rest-induced bone loss in women during 60-day simulated microgravity	Bone	2008
	Rittweger J, Frost HM, Schiessld H, Ohshima H, Alkner B, Tesch P, Felsenberg D.	Muscle atrophy and bone loss after 90 days' bed rest and the effects of flywheel resistive exercise and pamidronate: Results from the LTBR study	Bone	2005
	Belavy DL, Ohshima H, Bareille MP, Rittweger J, Felsenberg D.	Limited effect of fly-wheel and spinal mobilization exercise countermeasures on lumbar spine deconditioning during 90d bed-rest in the Toulouse LTBR study	Acta Astronautica	2011
	Trappe S, Costill D, Gallagher P, Creer A, Peters JR, Evans H, Riley DA, Fitts RH.	Exercise in space: human skeletal muscle after 6 months aboard the International Space Station	Journal of Applied Physiology	2009
	Fernández-Gonzalo R, Nissemark C, Åslund B, Tesch PA, Sojka P.	Chronic stroke patients show early and robust improvements in muscle and functional performance in response to eccentric-over-load flywheel resistance training: a pilot study	Journal of NeuroEngineering and Rehabilitation	2014
	Brasileiro JS, Pinto OM, Avila MA, Salvini TF.	Functional and morphological changes in the quadriceps muscle induced by eccentric training after ACL reconstruction	Brazilian Journal of Physical Therapy	2011
	Croisier JL.	Muscular Imbalance And Acute Lower Extremity Muscle Injuries In Sport	International SportMed Journal	2004
Isoinertial technology in fitness	Volkers KM, de Kieviet JF, Wittingen HP, Scherder EJ.	Lower limb muscle strength (LLMS): Why sedentary life should never start? A review	Archives of Gerontology and Geriatrics	2012
	Tous-Fajardo J, Maldonado RA, Quintana JM, Pozzo M, Tesch PA.	The Flywheel Leg-Curl Machine: Offering Eccentric Overload for Hamstring Development	International Journal of Sports Physiology and Performance	2006
	Bara-Filho M, Manso JG, Sarmiento S, Medina G.	Hamstrings co-contraction in knee extension during isoinertial strength work	Revista Brasileira de Biomecânica	2008
	Tomberlin JP, Basford JR, Schwen EE, Orte PA, Scott SC, Laughman RK, Ilstrup DM.	Comparative study of isokinetic eccentric and concentric quadriceps training	Journal of Orthopaedic & Sports Physical Therapy	1991
	Norrbrand L, Tous-Fajardo J, Vargas R, Tesch PA.	Quadriceps muscle use in the flywheel and barbell squat	Aviation, Space, and Environmental Medicine	2011
	Norrbrand L	Acute and early chronic responses to resistance exercise using flyweel or weights	Department of Physiology and Pharmacology, Karolinska Institute.	2008
	Fry AC, Schilling BK, Lohnes CA.	Kinetic and Kinematic Comparison Between Versa-Pulley and Free-Weight Front Squats	The University of Memphis, Department of Health & Sport Sciences	2007
	Norrbrand L, Pozzo M, Tesch PA.	Flywheel resistance training calls for greater eccentric muscle activation than weight training.	European Journal of Applied Physiology	2010
	Onambélé GL, Maganaris CN, Mian OS, Tamd E, Rejc E, McEwan IM, Narici MV.	Neuromuscular and balance responses to flywheel inertial versus weight training in older persons	Journal of Biomechanics	2008
	Goldmana EF, Jones DE.	Interventions for preventing hamstring injuries: a systematic review	Physiotherapy	2011
Isoinertial technology in injury prevention	Hibbert O, Cheong K, Grant A, Beers A, Moizumi T.	A systematic review of the effectiveness of eccentric strength training in the prevention of hamstring muscle strains in otherwise healthy individuals	North American Journal Of Sports Physical Therapy	2008
	Askling C, karlsson J, Thorstensson A.	Hamstring injury ocurrence in elite soccer players after preseasons strength training with eccentric overload	Scandinavian Journal Medicine and Science in sport	2003

Source: Own elaboration based on the data obtained in the study.

Isoinertial technology in rehabilitation

Usage for skeletal muscle injury management

In the rehabilitation of anterior cruciate ligament (ACL) injury, the study of Brasileiro (29) reports that eccentric strength training in the quadriceps muscle generates important functional and morphological changes; also, it shows that eccentric training significantly increased isokinetic torque and quadriceps area with greater hypertrophy in the proximal region, showing that eccentric training proves to be a powerful resource for recovery and strengthening the quadriceps, both morphologically and functionally.

Likewise, at muscle level, Croisier (40) shows that muscle function abnormalities can lead to persistent recurrent lesions and discomfort when resuming an activity. A rehabilitation program based on muscle strength training leading to the standardization of specific isokinetic parameters, with specific exercises according to the deficits, contributes to a decrease in symptoms during the return to field. Similarly, Croisier states that "some prospective studies have shown that preseason isokinetic testing in risk sports is useful to identify strength variables like the predictors of strained muscle in hamstring or adductor" (40, p13). Therefore, it can be said that muscle strength and intra and intermuscular coordination play a key role in acute muscle injuries.

In tendon injuries, a case study conducted in 10 male athletes who had patellar tendinitis showed that exercises using inertial eccentric overload in the short term improved eccentric strength by 90% ($p=0.03$), as well as the maximum concentric strength by 70%, which was evident in the quadriceps muscle, specifically in the femoral rectum. Regarding pain in the patellar tendon, as measured by the visual analog scale, it decreased after training by 60% ($p<0.01$) (41).

Usage in induced immobilization or simulated microgravity

Exercise protocol was used in the study conducted by Smith & Rittweger with women who went through induced rest for 60 and 90 days; the protocol combined exercise in bed and resistance exercise with flywheels for four days a week, in order to prevent bone resorption and promote bone formation. After the simulated microgravity, it was evident that, although the protocol did not provide an optimal bone countermeasure, it promoted bone formation and helped mitigate the net bone loss (42,43).

The findings suggest that both measures are partially effective in preserving bone mineral content (BMC) and muscle cross-sectional area (MCSA) of the leg during bed rest. The partial effectiveness of exercise with the flywheel and the response of bones to discharge makes evident the importance of mechanical stimuli; however, the huge variability of BMC changes suggests that other factors affect changes in bone strength (43).

In another study related to prolonged immobilization, changes in the parameters of the spine and posterior lumbar disc morphology after 90 days of bed rest are found. These results indicate that countermeasures used (measures taken before immobilization) were not optimal for maintaining the integrity of the spine and the trunk musculature during bed rest (44).

On the other hand, Trappe *et al.* (45), in a study of a crew traveling into space concluded that the exercise program did not completely protect the calf muscles in the absence of gravitational stimulus; also, they observed a substantial decrease in muscle mass of the calf and performance, along with a type of transition from slow to fast fibers in the gastrocnemius and the soleus. These data suggest that changes in the program of countermeasures exercise are required to protect the skeletal muscle while the crew are in space for long periods.

Usage in neurological or central nervous system diseases

Research reporting the use of these devices in neurological diseases are scarce and, also, contradictory. The study by Fernández-Gonzalo *et al.* (46) states that eccentric exercises with isoinertial technology generate muscular adaptations and functional performance in patients with chronic cerebrovascular accident. In contrast, another study in patients with degenerative neurological diseases did not find positive effects of isoinertial technology and shows greater benefits caused by concentric exercise (47), perhaps due to the type of neurological disease and its particular neuromuscular features, which requires further study.

Isoinertial technology in fitness

Currently, several studies report that the eccentric workout generates rapid strength gains compared to concentric work, since it shows that more tension is developed by using less active motor units and, therefore, less energy; similarly, neuronal conduction is improved, recruitment is more effective and greater inhibition of protective mechanisms is found. These factors make the crossbridge of the sarcomere develop greater strength and quantitatively determine that workout with eccentric strength can generate an average gain of 498±336J compared against 273±196J of concentric work. Within eccentric workout methods, isoinertial technology generates more overload that enhances the effects of this type of contraction (29-31).

According to Filho (32), strength training with the use of isoinertial machines is one of the current methods being used to improve physical capacity. Specifically, physical activity establishes the importance of proper development of the hamstring muscles to ensure muscle balance between them and the extensor muscles of the knee (quadriceps) since hamstrings work as synergists for actions like running. Some researchers, in different areas related to physical activity, thoroughly study the process of co-contraction of the hamstring muscles (33). Bernardi (34) states that the main objectives of the co-activation are related to the regulation of joint movement and control of joint stability, thus, co-activation of the hamstrings is necessary to stabilize the knee joint, equal the tension distribution on the surface of the joint and prevent cartilage damage.

Squats are the most practiced exercise in training to improve performance due to the development of horizontal or vertical strength, power and speed; however, in this exercise, muscle activation and recruitment of motor units are not generated in most repetitions, on the contrary, resistance achieves maximum motor action from the first repetition of a series with flywheel machines with isoinertial technology. The comparison between these different training methods allows establishing resistance using the flywheel to generate the maximum voluntary force by the rectus femoris muscle through each repetition of a set, increasing muscle tropism (35-37). The study by Onambélé (38) reports that the burden of inertia of the flywheel on the quadriceps causes an increase in muscle strength of the gastrocnemius of 26%, which leads to increased stiffness of the tendon by 136% with isoinertial technology; the increased rigidity is associated with an improvement in postural balance.

According to Tous (39), learning is an essential component for the execution of these exercises; given their complexity, it is important to provide immediate visual feedback to further adjust performance and control to allow the individual to get used to a correct manipulation of the isoinertial machine.

Clearly, the use of a greater moment of inertia results in higher production adaptations of eccentric force; likewise, muscle, power and speed improvements are much more influenced by the reduction of the moment of inertia. Although the optimal condition for improving quality distinctly varies among individuals, the general guidelines regarding the configuration of the moment of inertia is still undefined (24).

Isoinertial technology in injury prevention

The effectiveness of interventions used to prevent hamstring injuries in soccer players or those involved in other high risk activities has been demonstrated in randomized controlled trials (48), which state that the use of the isoinertial technology device yo-yo, in particular, reports a reduction in the incidence of hamstring strains in soccer players because it generates a considerable increase in strength of the biceps femoris muscle for greater eccentric activation. The above statement could suggest that the biceps femoris plays a much more relevant role in braking than the semitendinosus as there are no specific differences in strength, power and speed profiles caused depending on the moment of inertia applied during the year (24,35).

The results of a systematic review suggest that eccentric training is effective in primary and secondary prevention of hamstring strains. However, the heterogeneity of the studies and the poor methodological rigor limit the ability to provide clinical recommendations. More randomized clinical trials (RCT) are required to support the use of eccentric training protocols in preventing hamstring strains (49).

These results indicate that adding preseason strength training, specific for hamstring —including eccentric overload— would be beneficial for elite soccer players, for both injury prevention and performance improvement (50).

Conclusions

According to the literature, isoinertial technology is an important tool for rehabilitation and prevention of injuries that allows further development of force during the concentric and eccentric phases due to the particular functioning mechanism (33). This technology offers superior eccentric loads compared to traditional methods, where the co-activation of the hamstring muscles is greater; most studies are performed on this musculature, given the high prevalence of injury in soccer players. Generating high eccentric loads provides improved power and speed in the muscles, which is potentiated by reducing the moment of inertia (24). These effects are achieved at the end of the concentric action and by allowing the player to slow down, thus increasing the eccentric overload by decreasing the angular displacement (29).

As for the benefits of using the isoincercial technology for the treatment or management of some pathologies, studies demonstrating its effectiveness in recovering from ACL (29), patellar tendinopathy (40), as well as muscle-tendon injuries generated by muscle imbalance are found. Similarly, the isoinertial technology has proven to be beneficial in bone formation and in the decrease bone loss, as well as for increasing of muscle cross-sectional area during prolonged immobilization, which is important for the mechanical stimulus generated (42). It is also important to note that no changes were obtained in the morphology of the intervertebral disc using this technology due to the characteristics of the cartilage (44).

Although positive effects on muscle adaptations and functional performance in patients with sequelae of cerebrovascular disease (46) are found, a greater effect of the concentric exercises than of eccentric load generated by such technology is evidenced in patients with degenerative neurological diseases (47).

Regarding the prevention of sports injuries, it is reported that the use of this technology reduces the incidence of injury in the hamstring muscles, specifically in the biceps femoris —muscle with the highest rates of injury— (24,35,51). These results indicate that eccentric overload is beneficial for elite players in both injury prevention and performance improvement. However, few studies have used isoinertial technology, which raises the need for generating further research in the field.

Isoinertial technology is an important tool for the prevention of sport injuries, as it allows functional movements related to the sporting context and an increase of eccentric load during the workout. Similarly, it is important for inclusion to promote the construction of a protocol using these machines, which will unify parameters and ensure optimal stimulus in the development of responses and musculoskeletal adaptations.

The scientific literature shows the benefits of isoinertial technology; nonetheless, there are few experimental studies to determine the effect of preventing musculoskeletal injuries in athletes, in controlling them and in pathological conditions caused by immobilization processes or alterations of the central nervous system.

This review opens a field of research in injury management, control and prevention, which must be explored from analytical and experimental studies to determine their effect and efficacy, while promoting rehabilitation processes and functional rehabilitation.

Conflict of interests

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References

1. **Fousekis K, Tsepis E, Poulmedis P, Athanasopoulos S, Vagenas G.** Intrinsic risk factors of non-contact quadriceps and hamstring strains in soccer: a prospective study of 100 professional players. *Br. J. Sports. Med.* 2011;45(9):709-14. http://doi.org/bcjtrx.
2. **Ekstrand J , Hägglund M, Waldén M.** Epidemiology of muscle injuries in professional football (soccer). *Am. J. Sports Med.* 2011;39(6):1226-32. http://doi.org/bzbrcq.
3. **Petersen J, Thorborg K, Nielsen MB, Budtz-Jørgensen E, Hölmich P.** Preventive effect of eccentric training on acute hamstring injuries in men's soccer: a cluster-randomized controlled trial. *Am. J. Sports Med.* 2011;39(11):2296-303. http://doi.org/bpp4tv.
4. **Woods C, Hawkins RD, Maltby S, Hulse M, Thomas A, Hodson A, *et al.*** The Football Association Medical Research Programme: an audit of injuries in professional football—analysis of hamstring injuries. *Br. J. Sports Med.* 2004;38(1):36-41. http://doi.org/fg35vr.
5. **Pruna R.** Muscle Injuries Guide 3.0. Barcelona: FC Barcelona and Aspertar; 2015 [cited 2014 Oct 10]. Available from: http://goo.gl/fTYwwi.
6. **Gianotti S, Hume PA.** A cost-outcome approach to pre and post-implementation of national sports injury prevention programmes. *J. Sci. Med. Sport.* 2007;10(6):436-46. http://doi.org/ccnzjp.

7. **Ciullo JV, Zarins B.** Biomechanics of the musculotendinous unit: Relation to athletic performance and injury. *Clin. Sports Med.* 1983;2(1):71-86.
8. **Meeuwisse WH.** Assessing causation in sport injury: a multifactorial model. *Clin. J. Sports Med.* 1994;4(3):166-70. http://doi.org/fwgc7s.
9. **Orchard JW.** Intrinsic and extrinsic risk factors for muscle strains in Australian football. *Am. J. Sports Med.* 2001;29(3):300-3.
10. **Lu TW, Chien HL, Chang LY, Hsu HC.** Enhancing the Examiner's Resisting Force Improves the Validity of Manual Muscle Strength Measurements: Application to Knee Extensors and Flexors. *J. Strength. Cond. Res.* 2012;26(9):2364-71. http://doi.org/ctrgxx.
11. **Croisier JL, Ganteaume S, Binet J, Genty M, Ferret JM.** Strength imbalances and prevention of hamstring injury in professional soccer players. *Am. J. Sports Med.* 2008;36(8):1469-75. http://doi.org/fkn53m.
12. **Garrett WE Jr.** Muscle strain injuries. *Am. J. Sports Med.* 1996;24(6 Suppl):S2-8.
13. **Safran MR, Seaber AV, Garrett WE Jr.** Warm-up and muscular injury prevention: an update. *Sports Med.* 1989;8(4):239-49. http://doi.org/cx629j.
14. **Tais S.** Transfer Mechanisms of eccentric training. The effects of EMG-biofeedback in training. [Tesis]. Stockholm: The swedish school of sport and health sciences; 2011 [cited 2014 Oct 10]. Available from: http://goo.gl/XgJmyY.
15. **Clark RA.** Hamstring injuries: risk assessment and injury prevention. *Ann. Acad. Med. Singapore.* 2008;37(4):341-6.
16. **McHugh MP, Connolly DA, Easton RG, Gleim GW.** Exercise-induced muscle damage and potential mechanisms for the repeated out effect. *Sports Med.* 1999;27(3):157-170. http://doi.org/b593vh.
17. **McHugh MP.** Recent advances in the understanding of the repeated bout effect: the protective effect against muscle damage from a single bout of eccentric exercise. *Scand. J. Med. Sci. Sports.* 2003;13(2):88-97. http://doi.org/fdssqw.
18. **Nosaka K, Saldanha-Aoki M.** Repeated Bout Effect: Research Update and Future Perspective. *Brazilian Journal of Biomotricity.* 2011;5(1):5-15.
19. **Nosaka K, Newton MJ, Sacco P.** Attenuation of protective effect against eccentric exercise induced muscle damage. *Can. J. Appl. Physiol.* 2005;30(5):529-542. http://doi.org/bzn456.
20. **Souza-Teeixeira F, de Paz JA.** Eccentric Resistance Training and Muscle Hypertrophy. *J. Sport Medic. Doping Studie.* 2012;S1(1). http://doi.org/bj43.
21. **Roig M, Shadgan B, Reid WD.** Eccentric exercise in patients with chronic health conditions: a systematic review. *Physiother Can.* 2008;60(2):146-60. http://doi.org/dmnvnx.
22. **Miller PC, Hall EE, Chmelo EA, Morrison JM, DeWitt RE, Kostura CM.** The influence of muscle action on heart rate, RPE, and affective responses after upper-body resistance exercise. *J. Strength Cond. Res.* 2009;23(2):366-72. http://doi.org/fpgjrb.
23. **Chiu LZ, Salem GJ.** Comparison of joint kinetics during free weight and flywheel resistance exercise. *J. Strength Cond. Res.* 2006;20(3):555-62. http://doi.org/ddzprw.
24. **Romero-Rodríguez D, Tous-Fajardo J.** Prevención de lesiones en el deporte. Claves para un rendimiento óptimo. Madrid: Editorial Panamericana; 2010.
25. **Berg HE, Tesch PA.** Force and power characteristics of a resistive exercise device for use in space. *Acta Astronaut.* 1998;42(1-8):219-230. http://doi.org/dpk6qd.
26. **Linaza-Bao A.** Entrenamiento Con Versa-Pulley (Polea Cónica). Máquinas Isoinerciales. G-SE; 2013 [cited 2014 Oct 14]. Available from: http://goo.gl/imFOwi.
27. **Tous J, Pozzo M.** The Isoinertial Technology. In: Avances en entrenamiento de la fuerza. Madrid: Universidad Europea de Madrid; 2007 [cited 2014 Nov 10 2014]. p. 145-156. Available from: https://goo.gl/JZn8SN
28. **Vazquez-Guerreo J, Moras G.** Changes in muscular architecture and execution velocity during squats performed using the versapulley under stable and unstable conditions in junior elite basketball players. *Cuadernos de Psicología del Deporte.* 2015;15(3):243-252.
29. **Brasileiro JS, Pinto OM, Avila MA, Salvini TF.** Functional and morphological changes in the quadriceps muscle induced by eccentric training after ACL reconstruction. *Rev. Bras. Fisioter.* 2011;15(4):284-90. http://doi.org/dw3m84.
30. **Norrbrand L.** Acute and early chronic responses to resistance exercise using flyweel or weights. [Tesis]. Stockholm: Karolinska Institute; 2008 [cited 2014 Dec 10]. Available from: https://goo.gl/nP8fkN.
31. **Tomberlin JP, Basford JR, Schwen EE, Orte PA, Scott SC, Laughman RK, *et al.*** Comparative study of isokinetic eccentric and concentric quadriceps training. *J. Orthop. Sports Phys. Ther.* 1991;14(1):31-6. http://doi.org/bj26.
32. **Bara-Filho M, Manso JG, Sarmiento S, Medina G.** Hamstrings co-contraction in knee extension during isoinertial strength work. Revista Brasileira de *Biomecânica.* 2008;9(16):13-17.
33. **Caruso JF, Hernández DA.** Net caloric cost of a 3-set flywheel ergometer resistence exercise paradigm. *J. Strength Cond. Res.* 2002;16(4):567-72. http://doi.org/fc4b74.
34. **Bernardi M, Solomonov M, Sánchez JH, Baratta RV, Nguyen G.** Motor unit recruitment strategy of knee antagonist muscle in step-wise, increasing isometric contraction. *Eur. J. Sports Physiol.* 1995;70(6):493-501. http://doi.org/bd4h6b.
35. **Norrbrand L, Pozzo M, Tesch PA.** Flywheel resistance training calls for greater eccentric muscle activation than weight training. *Eur. J. Appl. Physiol.* 2010;110(5):997-1005. http://doi.org/bdbd3d.
36. **Norrbrand L, Tous-Fajardo J, Vargas R, Tesch PA.** Quadriceps Muscle Use in the Flywheel and Barbell Squat. *Aviat. Space Environ. Med.* 2011;82(1):13-9. http://doi.org/b9dq2c.
37. **Fry AC, Schilling BK, Lohnes CA.** Kinetic and Kinematic Comparison Between Versa-Pulley and Free-Weight Front Squats. Menphis: The University of Memphis. 2007.
38. **Onambélé GL, Maganaris CN, Mian OS, Tamd E, Rejc E, McEwan IM, *et al.*** Neuromuscular and balance responses to flywheel inertial versus weight training in older persons. J. Biomech. 2008;41(15):3133-8. http://doi.org/c2zwzf.
39. **Tous-Fajardo J, Maldonado RA, Quintana JM, Pozzo M, Tesch PA.** The Flywheel Leg-Curl Machine: Offering Eccentric Overload for Hamstring Development. *Int. J. Sports Physiol. Perform.* 2006;1(3):293-8.
40. **Croisier JL.** Muscular imbalance and acute lower extremity muscle injuries in sport. *International SportMed Journal*. 2004;5(3):169-176.
41. **Romero-Rodríguez D, Gual G, Tesch PA.** Efficacy of an inertial resistance training paradigm in the treatment of patellar tendinopathy in athletes: A case-series study. *Phys. Ther. Sport.* 2011;12(1):43-8. http://doi.org/bvx248.
42. **Smith SM, Zwart SR, Heer M, Lee SM, Baecker N, MEuche S, *et al.*** WISE-2005: Supine treadmill exercise within lower body negative pressure and flywheel resistive exercise as a countermeasure to bed rest-induced bone loss in women during 60-day simulated microgravity. Bone. 2008;42(3):572-81. http://doi.org/dxzq9x.
43. **Rittweger J, Frost HM, Schiessl H, Ohshima H, Alkner B, Tesch P, *et al.*** Muscle atrophy and bone loss after 90 days' bed rest and the effects of flywheel resistive exercise and pamidronate: results from the LTBR study. Bone. 2005;36(6):1019-29. http://doi.org/fn74w8.
44. **Belavy DL, Ohshima H, Bareille MP, Rittweger J, Felsenberg D.** Limited effect of fly-wheel and spinal mobilization exercise countermeasures

on lumbar spine deconditioning during 90d bed-restin the Toulouse LTBR study. *Acta Astronaut.* 2011;69(7-8):406-19. http://doi.org/dq957w.

45. **Trappe S, Costill D, Gallagher P, Creer A, Peters JR, Evans H, *et al.*** Exercise in space: human skeletal muscle after 6 months aboard the International Space Station. J. Appl. Physiol. 2009;106(4):1159-68. http://doi.org/fcgdqb.

46. **Fernández-Gonzalo R, Nissemark C, Åslund B, Tesch PA, Sojka P.** Chronic stroke patients show early and robust improvements in muscle and functional performance in response to eccentric-overload flywheel resistance training: a pilot study. *J. Neuroeng Rehabil.* 2014;11:150. http://doi.org/f3nmvv.

47. **Ponichtera JA, Rodgers MM, Glaser RM, Mathews TA, Camaione DN.** Concentric and Eccentric Isokinetic Lower Extremity Strength in Persons with Multiple Sclerosis. *J. Orthop. Sports Phys. Ther.* 1992;16(3):114-22. http://doi.org/bj46.

48. **Goldmana EF, Jones DE.** Interventions for preventing hamstring injuries: A systematic review. *Physiotherapy.* 2011;97(2):91-9. http://doi.org/bqwk65.

49. **Hibbert O, Cheong K, Grant A, Beers A, Moizumi T.** A systematic review of the effectiveness of eccentric strength training in the prevention of hamstring muscle strains in otherwise healthy individuals. N. Am. J. Sports Phys. Ther. 2008;3(2):67-81.

50. **Askling C, karlsson J, Thorstensson A.** Hamstring injury ocurrence in elite soccer players after preseasons strength training with eccentric overload. *Scand. J. Med. Sci. Sport.* 2003;13(4):244-50. http://doi.org/cw7jzm.

51. **Daneshjoo A, Rahnama N, Mokhtar AH, Yusof A.** Effectiveness of Injury Prevention Programs on Developing Quadriceps and Hamstrings Strength of Young Male Professional Soccer Players. *J. Hum. Kinet.* 2013;39:115-25. http://doi.org/bj47.