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CLINICAL COMMENTARY

FLYWHEEL TRAINING IN MUSCULOSKELETAL REHABILITATION: A CLINICAL COMMENTARY

Jaap Wonders,[1]

ABSTRACT

Flywheel training is a relatively new method used to train the human body with continuous resistance and eccentric overload. The performed exercises result in improvements of strength and power, hypertrophy, muscle activation, muscle length, and tendon stiffness. Other positive effects of flywheel training are athletically relevant improvements in things such as speed, jump height and change of direction. The positive results can be explained by the eccentric and power characteristics of the training, making flywheel training ideal for use in musculoskeletal rehabilitation. Flywheel training can be used for injury prevention, training after a period of unloading, tendon and muscle rehabilitation, as part of post-operative rehabilitation, during late stage sport specific rehabilitation as well as for fall prevention and treatment of sarcopenia among elderly. The purpose of this commentary is to inform physical therapists about the use of flywheel training in musculoskeletal rehabilitation.

Keywords: eccentric overload, flywheel training, power training, rehabilitation, tendinosis, movement system

Level of evidence: 5

CORRESPONDING AUTHOR

Jaap Wonders
SMC Rijnland, Oosterkerkstraat 1a 2312 SN
Leiden, The Netherlands
E-mail: jaap@smc-rijnland.nl

[1] SMC Rijnland Fysiotherapeuten, Leiden, The Netherlands

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INTRODUCTION

Flywheel training is a relatively new training method used by physical therapists. The positive effects of flywheel training in fitness and training are well documented and multiple reviews have been written.[4,5,6,7,8,9] However, flywheel training has received scant attention in the rehabilitation and sports physical therapy literature. This clinical commentary will address the value of flywheel training in musculoskeletal rehabilitation.

A flywheel is heavy wheel, measured in inertia, that needs externally applied force to spin around. The force required to set it spinning is also needed to make it stop. When a flywheel is spinning at high speed, it will keep spinning because of the angular momentum it has. This means it can store kinetic energy like a battery. The heavier and larger the flywheel, the more energy it can store. Speed is key in flywheel training. A flywheel that spins faster stores much more energy than one that spins slower. A variety of different flywheel devices are used in training settings, for instance boxes and pulleys (figure 1). It is important that those devices have minimal friction by the rope to maintain high speed. The axis of the device has to be relatively big and light to keep the kinetic energy stored. The athlete or patient needs to move to keep the flywheel spinning and will do so by using his or her strength and power. Power training using a flywheel is an explosive way of training by which muscles will contract at maximum force in minimum time.

The use of a flywheel device for muscle training goes back to 1913 when Swedish researchers published regarding the physiology of muscles using a bicycle ergometer with a flywheel for resistance.[1,2] In 1994 other exercise physiology scholars from

Figure 1. *Flywheel pulley (above) and flywheel box (below).*

Sweden developed and validated a flywheel ergometer to prevent muscle atrophy and loss of strength by astronauts in space.[3] Because flywheel training is gravity independent, it has been used for resistance training by astronauts in space ever since.[4] The gravity-independent character of flywheel exercises results in continuous resistance and eccentric overload. This isoinertial type of resistance facilitates optimal muscle force generation throughout all the angles of a movement. Improvements in muscle strength are experienced throughout the full range of motion. In addition, greater eccentric muscle activation occurs during flywheel training compared with normal weight training.[5] The purpose of this commentary is to inform physical therapists about the use of flywheel training in musculoskeletal rehabilitation. To this end, the effects of flywheel training and the physiology behind these positive effects are summarized. Second, the use of a flywheel in prevention and rehabilitation of musculoskeletal injuries will be discussed.

TRAINING EFFECTS

A vast amount of research has shown that flywheel training is effective in increasing strength, hypertrophy, muscle activation, muscle length, tendon stiffness and power.[4,5,6,7,8,9] In addition to these physiological benefits, flywheel training results in athletically relevant improvements. Increases in speed, jump height and change of direction are documented in a number of scientific articles.[4,7,9] A review by Tesch et al.[4] described the benefits of flywheel training for healthy individuals, athletes, astronauts, elderly, musculoskeletal and neurological patients as well as how it can assist in injury prevention among athletes.[4] One of those benefits is that compared with weight training, flywheel training has demonstrated greater global EMG activity and greater muscle use, as measured by functional magnetic resonance imaging (fMRI).[4] Another benefit identified in the review is the improvement of the post-activation potentiation (PAP) phenomenon, which refers to athletes improving in speed during their sports activity shortly after performing a bout of flywheel exercise.[4] A systematic review and meta-analysis by Maroto-Izquierdo et al.[7] provides more detailed information regarding the adaptations that occur in muscle tissue of healthy and trained individuals after performing flywheel training.[7] According to Maroto-Izquierdo et al.[7] compared with weight resistance training, flywheel training results in greater improvements in muscle power, muscle hypertrophy, and athletically relevant elements such as vertical jump height and running speed.[7]

When using flywheel training in musculoskeletal rehabilitation, it is important for the therapist to know the physiology behind the exercises in order to optimize the benefits. This way the therapist can make better informed decisions, resulting in improved outcomes for the patient. So why does flywheel training give good results? Power training and eccentric overload training are two characteristics of flywheel training that can explain the positive results found in scientific research. The ability to train with high speed and high power implies that the exercises closely resemble many functional and athletically relevant movements. Flywheel training makes use of the stretch-shortening cycle, leading to, compared with weight resistance training, greater efficiency in the stretch-shortening cycle, higher specificity and enhanced adaptation during rehabilitation.[8,9] Another noteworthy physiological change that has been documented after flywheel training is the hypertrophy of type II muscle fibers.[9] Importantly, the described effects occur without triggering pain in patients with a musculoskeletal injury.[8]

Skeletal muscle shows increased peak torque during eccentric movement compared with concentric movement.[9,10] The explanation for the increased peak torque during eccentric movement can be found in the two-state cross bridge model.[10] Actin and myosin cross bridges will quickly detach and reattach and thick filaments will rearrange.[10] The giant titin protein, an additional filament in muscles, plays an important role during eccentric contraction by creating stiffness in the muscles.[10] This eccentric action is highlighted during flywheel training, resulting in an eccentric overload when performing exercises.[5,7]

Exercises with eccentric overload activate various genes that trigger protein functions, for instance protein synthesis and sarcomerogenesis.[11] Higher intra-muscular pressure during eccentric movements (compared to concentric movements) leads to hypoxia, which enhances gene expression.[11] The activated protein functions result in changes at the cellular level like membrane biosynthesis, stress management by stress-responsive genes, repair, growth and remodeling.[11] Additionally, there will be less activation of myostatin and more activation of the IGF-growth factor.[11] Gene activation followed by enhanced protein and cellular functions leads to recovery and adaptation of the trained muscles.[11] Muscles will become stronger, thicker, faster and more powerful. Eccentric contractions produce high forces with low energy costs and result in positive outcomes, making them well suited for training and rehabilitation.[10]

REHABILITATION

Flywheel training is used by astronauts in space to prevent muscle atrophy and loss of strength, as mentioned earlier.[3] Other researchers have shown that flywheel training is effective to mitigate the negative effects of unloading, for instance after a period of bed rest or casting.[4]

Prevention of musculoskeletal and sports injuries is another potential objective of flywheel training.[4,12,13,14] The main goal of the use of this type of training is to decrease injury risk factors. Several studies have shown the positive effects of flywheel training on injury prevention.[12,13,14] In two different studies, soccer players performed a ten-week program of flywheel exercises (squat and leg-curl) and experienced a significant decrease in lower limb muscle injuries during the season.[12,13] Another study, which compared volleybal players who performed a six-week program of flywheel training compared with those who performed body weight exercises showed that flywheel training group experienced positive adaptations (improved tuck jump assessment and valgus scores, improved hamstring concentric and eccentric peak torque, and improved repeated shuttle sprint ability) that can decrease the risk of hamstring and Anterior Cruciate Ligament (ACL) injuries.[14]

A variety of training methods have been proven to be effective in the treatment of tendon injuries and are commonly used by therapists.[15,16,18,19] Eccentric training for injured tendons leads to a reduction in pain, decreased stiffness in the tendon, increased neovascularization, enhanced neuroplasticity, and increased shielding of muscles.[10,15,17] For example, Achilles tendon and patellar tendon both react positively to eccentric training,[10] shoulder rotation eccentric training is effective for subacromial pain syndrome,[16] and eccentric training improves outcomes in patients with lateral and medial epicondylosis.[17] Although the majority of studies focus on the benefits of eccentric training on tendinosis, heavy-slow resistance training and a combination of eccentric and concentric training have also been shown to have positive effects.[18] According to the findings of Maliaras et al.[19] in their systematic review, there is not enough evidence for isolating the eccentric component during the rehabilitation of tendinosis, therefore, it has been suggested to use exercises with both a concentric and eccentric component.[19] This makes flywheel training that has both concentric action and eccentric overload an ideal choice for tendinosis rehabilitation. Tesh et al.[4] and Gual et al.[8] suggest that flywheel training can play a big role in tendon rehabilitation.[4,8] The positive outcomes occur without triggering complaints caused by the tendinosis.[8] For example, flywheel squats improve the quality of patellar tendon and Achilles tendon, indicated by an increase in the cross-sectional area of the tendon.[20,21]

When examining the positive training effects of flywheel training, it is evident that it is an effective tool for muscle injury rehabilitation. The gains in strength, hypertrophy, muscle activation and muscle length will lead to positive adaptations and muscle healing. To use the example of rehabilitation after a calf muscle strain, flywheel training can be used by performing squats and lunges in the second week after the onset of the injury. Flywheel squats have been shown to lead to structural adaptations in the gastrocnemius muscle.[21] Calf raises as a flywheel exercise can be performed in the proliferation and reorganization stages of the healing process for calf muscles. Thus, traditional early rehabilitation and flywheel training in combination with strength training and functional exercises could result in enhanced outcomes in patients after calf strain.[22,23]

Another group of patients that can benefit from flywheel training are those after surgery, when atrophy and loss of muscle strength occurs rapidly. For example, in rehabilitation after anterior cruciate ligament reconstruction, patients need quadriceps strength and muscle power to be able to walk, run

Table 1. *Information on manufacturers and costs of varied types of Flywheel equipment.*

Manufacturer	Devices	Website	Cost
RSP	Box and pulley	https://einercial.com	$2,500-$4,000 USD
Kynett	Box and pulley	https://www.kynett.com	$1,100-$4,000 USD
Exxentric	Box and pulley	https://exxentric.com	$2,000-$5,400 USD
nHANCE	Box and fitness machines	http://nhance.se	$2,000-$5,000 USD
Desmotec	Box and pulley	http://desmotec.com	$3,400-$7,000 USD
Versaclimber	Pulley	https://versaclimber.com	$2,000-$6,100 USD

and jump again.[24] Flywheel training addresses both strength and power and can be used in most stages of rehabilitation together with mobility and stability exercises, neuromuscular training, plyometric exercises, running drills and athletically relevant tasks.[24,25]

Late-stage rehabilitation of musculoskeletal injuries requires training of the kinetic chain and explosive power training. Flywheel training will address both and can therefore be used for different injuries when return to sports or work is needed.[26] Complementary to flywheel training, training methods such as plyometrics, olympic weightlifting and running drills can be used in this phase of rehabilitation. One can think of shoulder rehab using the flywheel pulley or knee rehab using the flywheel box. Exercises that are task and sport specific are required to gain optimal results. For example, a field-hockey player in late-stage rehabilitation after an anterior cruciate ligament reconstruction can perform flywheel box exercises such as squats and lunges, which are closely related to field-hockey movements and can improve aspects of the neuromuscular system.[14,24,26] An other example would be a tennis player with rotator cuff injury who can benefit from sport-specific exercises such as flywheel pulley exercises mimicking a tennis backhand, which can improve functional outcomes benefiting return to play.[16,26]

Last but not least, the elderly can benefit from flywheel training.[4] To prevent and treat sarcopenia, flywheel training can be used for the whole body.[4] For example squat exercises using the flywheel box or core rotations using the flywheel pulley. Fall prevention is another aim for which to use a flywheel device.[4] Flywheel training will strengthen muscles and improve muscle power as well as muscle reactivity. Strength, power and reactivity are all important for the elderly to keep them moving functionally, prevent them from falling, and maintain muscle health.[26]

It is recommended that flywheel training with the elderly and patients with musculoskeletal injuries be conducted once or twice a week with low intensity, low speed and medium inertia in the beginning of the rehabilitation and training.[4,26] When elderly and patients perform the exercises in a well-coordinated manner and hardly experience any pain, intensity and speed can be increased.[4,26] As inertia is increased, the training focuses more on strength and hypertrophy, while lower inertia and higher speed results in more explosive training sessions with higher power outputs. Four sets of eight to twelve repetitions with 90 to 120 seconds of rest between sets is preferable.[4,26] The therapist can choose to change these training variables depending on the site of the injury, phase of rehabilitation, amount of pain, and objectives of the training.[4,26]

CONCLUSION

This clinical commentary provides an overview for physical therapists regarding the scientific evidence and practical implications of flywheel training in musculoskeletal rehabilitation. Flywheel training results in numerous and varied improvements in muscles, tendons and other connective tissue. Improvements in strength, hypertrophy, muscle activation, muscle length, tendon stiffness, power, and athletically relevant performance have all been documented. Such outcomes make flywheel training ideal for musculoskeletal rehabilitation. This commentary underscores the important role that flywheel training can play in tendon rehabilitation. Prevention and rehabilitation of muscle and joint injuries and training of fragile elderly are other applications for which flywheel training can be used. Additional studies are required to draw definite conclusions about the use of flywheel training in general musculoskeletal and post-operative rehabilitation.

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