Reinforcement Motor Learning in a Return-to-Duty Protocol

Teaching Plyometric Technique for Soldiers with Recent ACL Injury

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Introduction

Lower-body plyometrics – or exercises which train muscles to achieve maximal force in the lowest amount of time (Haff & Triplett, 2016) – serve a valuable role in nearly all strength and conditioning programs. Plyometric training confers a variety of beneficial adaptations to not only the musculoskeletal system, but the neuromuscular as well. It is highly beneficial to utilize it for power development and speed training (Davies et al., 2015; Haff & Triplett, 2016), and it has been demonstrated that performing plyometrics immediately prior to events and competitions which require elevated expressions of speed and power is beneficial in the subsequent event (Karampatsos et al., 2017). Speed and power athletes are not the only ones whose performance can be augmented by plyometric training, as it is very beneficial for endurance athletes as well (Lum et al., 2019; Li et al., 2019; Wei et al., 2020). Clearly, the inclusion of lower-body plyometrics in the training programs of athletes throughout multiple sports and activities is merited. The benefits of plyometric training are not limited to solely performance enhancement, however, as it also plays a large role in the prevention and rehabilitation of ACL injury (Nessler et al., 2017; Buckthorpe & Della Villa, 2021). Due to its utility in both injury prevention and rehabilitation, various members of military human performance teams, including strength and conditioning coaches, physical therapists, and athletic trainers can all utilize plyometric training to enhance health and fitness outcomes for the servicemembers that they work with.

The existence of many levels of plyometric exercises requires that an athlete begin at the most basic level and progress upward, both to reduce injury risk as well as to ensure that motor patterns are efficient and muscles able to recruit force in a coordinated and efficient manner. The graduation principle holds that the body must go through progressive stages in training (in which it 'graduates' from one level of exercise to the next) in order for the body to avoid injury and truly reap the benefits of more advanced training methods. This principle is of great importance regarding plyometrics, especially when they are being employed in an ACL rehabilitation program. For example, to help avoid poor learning and overuse injury, an athlete would not perform unilateral and/or depth jumps prior to learning proper landing technique or take-off technique and progressing through less advanced exercises prior. Understanding the progression of motor skill development and how force is produced in plyometrics is of great importance when teaching plyometric exercise. Not only this, but coaches and therapists must know how to employ beneficial reinforcement and goal setting strategies that are rooted in motor learning principles to most effectively help their athletes move toward full recovery.

Purpose Statement

The purpose of this paper is to explore the use of reinforcement strategies and goal-setting through a hypothetical case study of teaching lower body plyometric techniques in the rehabilitation program of two recently injured soldiers during their return-to-duty protocol. Two Apache pilots – one female and one male – suffered ACL tears in a helicopter crash. After surgery, recovery, and an initial several weeks of physical therapy, they have been sent to the unit's strength and conditioning coach to work on basic plyometric technique in order to begin a progression toward full-speed training. The coach, based upon the growing body of literature in motor learning and rehabilitation (Brinkman et al., 2020; Coppack et al., 2012), has decided to make an intentional effort to employ goal setting and reinforcement strategies when working with these two tactical athletes.

Overview of Athletes

As stated in the previous section, the athletes in this hypothetical case study are two Apache helicopter pilots (comprising one crew) who both suffered ACL injuries in a crash. Due to the trajectory of the crash and force vectors placed upon them as their aircraft contacted the ground, shearing forces were

placed on their left knees, resulting in similar tears to their anterior cruciate ligaments. In order to ensure that similar injuries do not occur in the future as well as to improve tactical performance parameters, their rehabilitation plan includes the introduction of lower body plyometric exercises, which, as stated in the introduction, can play a major role in ACL injury prevention. Due to the injury itself, the integrity of the knee joint will be lessened, and future landing, cutting, or changing direction (the primary causes of ACL injury), could result in re-injury if the joint is not properly strengthened, both from musculoskeletal and proprioceptive perspectives.

These athletes are highly motivated, disciplined, and dedicated to returning to full duty in better physical and mental condition than they were before their injuries. Due to the injuries, they have missed a deployment that many in their unit were sent on, and this has made them even more motivated to return to duty in order to be able to deploy in the future with their unit. The female pilot is aware that women are three times more likely to suffer an ACL rupture than men due to intrinsic biomechanical factors (Sutton & Bullock, 2013), which causes her to be extra motivated to focus fully on her return-to-duty program.

A two-man aircrew, they are used to placing their lives in each other's hands in the most difficult of situations. They are solid friends and are incredibly competitive with each other in training, which has historically resulted in better performance outcomes from them individually and as a crew. This competitiveness is known to their strength and conditioning coach, and will be used to assist in the reinforcement techniques applied during their training sessions.

A Brief Overview of Goal Setting and Reinforcement

Within the disciplines of both motor learning and sports psychology, goal-setting is a key strategy to help athletes and learners take ownership of their development and enhance motivation. It is employed often by strength and conditioning coaches (Quartiroli et al., 2020) and is recognized as highly effective in assisting athletes and learners with factors such as: self-efficacy (Brinkman et al., 2019; Evans & Hardy, 2002), improved performance (McCormick et al., 2015), and adherence to exercise programs (Bycura et al., 2018). Knowing an athlete's goals can help the coach or therapist to use specific reinforcement strategies which can best help to motivate them.

Reinforcement is also an important concept which can assist athletes to improve their motor skill learning. Reinforcement refers to an action, event, or providing feedback (which can take many forms) to increase the likelihood that a response will occur again. In other words, reinforcement is meant to strengthen the response that is desired in a given learning situation. Two primary types of reinforcers, which if applied correctly can improve both motor learning and performance, are positive and negative reinforcement, explained below, while reinforcement can also be classified as external, internal, and vicarious.

Positive reinforcement occurs when a coach or teacher acts to increase the likelihood that a given behavior will occur again by following the behavior with a positive action such as praise; negative reinforcement also seeks to increase the likelihood of the behavior again occurring, though in this case is accomplished by removing a usually undesirable event or action (Haff & Triplett, 2016). An example of positive reinforcement could be a coach clapping and saying, "Good, good! Way to go!" or fist bumping a basketball player when he or she comes out of the game for a rest. Negative reinforcement could take the form of trainees not having to perform another set of conditioning sprints at the end of a training day if the entire unit finishes a set in under a certain time.

Literature Review

As stated above, a coach or therapist having an understanding of goal-setting and reinforcement learning strategies are of immense importance in assisting an athlete return to health after an injury. For this reason, this paper includes a literature review of studies and research which explore the role of these two important motor learning concepts in the musculoskeletal rehabilitation programs. As will be demonstrated, a coach or a clinician being able to implement goal-setting and reinforcement strategies in return-to-duty or return-to-play protocols is beneficial to athletes. The first portion of the literature review covers the implementation of goal-setting, and the second looks at the role of reinforcement learning in the overall context of motor learning principles in the rehabilitation setting.

Coppack et al. (2012) examined the impact of a goal-setting intervention on multiple outcome parameters in a low-back pain rehabilitation program of military personnel. Three groups of subjects (48 in total) underwent a three-week treatment program at the United Kingdom's Defence Medical Rehabilitation Centre in Headley Court. Groups were divided into a goal-setting experimental group, a therapist-led group

(C1 – without goal-setting), and a non-therapist-led exercise therapy group (C2 – also without goal-setting). Each group performed the same exercise program throughout the study.

A major component of this study was the inclusion of goal-setting within the framework of performance profiling, which includes the patient or athlete to help establish goals that might be motivating for the individual. The primary outcome parameters quantified for this study were: self-efficacy, treatment efficacy, adherence, and treatment outcomes. The researchers hypothesized that the goal setting intervention would help to enhance the measures of adherence, perception of self-efficacy, and treatment outcome.

The results of the study partially supported the hypothesis. They demonstrated that adherence scores were significantly higher in the goal-setting group when compared to the C2 group, though not compared to the C1 group. However, the goal-setting group did exhibit significantly higher scores than both other groups on self-efficacy measures. The researchers concluded that self-efficacy, or one's belief in one's ability to act in a way that will help them achieve goals, may have been augmented in the goal-setting group due to performance profiling.

Results for treatment efficacy did not yield any significant difference between either of the groups, though the highest mean value was present in the goal-setting group and the C2 group showed a decrease in treatment efficacy over the course of the study (attributed to this latter group not having received verbal encouragement during the study). The researchers believed that the sample size may have been too small to yield significant results regarding treatment efficacy. Contrary to the hypothesis, the researchers found no significant improvements in treatment outcome of the goal-setting group when compared to the other two groups. Sample size was also considered by the researchers as a possible contributor to this, as they felt that the data contradicted other research which showed connections between self-efficacy and treatment outcome measures. The possibility of more severe pathologies in some subjects than others was also attributed as a possible reason for treatment outcome not being significantly better in the goal-setting group.

The primary clinical messages from the researchers, in conclusion, included the following: that goal-setting may improve self-efficacy, treatment efficacy, and adherence; and that encouragement, supervision, and explanation of the benefits of the treatment program can increase adherence.

Leech et al. (2022) provided an in-depth overview of updates in the application of motor learning in the rehabilitation setting on account of the growth in motor learning research and recent years. The researchers focused on four of the primary mechanisms through which motor learning occurs, namely

use-dependent, instructive, reinforcement, and sensorimotor adaptation. These mechanisms, the researchers say, are each governed by different neural substrates and can contribute either in isolation or in parallel to help drive motor learning. In their review, they provide insights into how each of the above mechanisms can be leveraged in the physical therapy setting to improve human movement and patient outcomes.

The researchers emphasize that motor learning is centered around plasticity in the nervous system and the body's ability to drive these adaptations through repeated practice of new movements. This motor learning can be promoted in rehabilitation settings through structuring interventions with it in mind, and motor learning knowledge will allow physical therapists to diversify the ways in which they can influence movement rehabilitation. Due to new and recent advances in motor learning as it applies to rehabilitation, the researchers state that these updates should be reflected in physical therapy curricula.

As motor learning is multifaceted, the researchers focused on four mechanisms of motor learning, as stated above, which can either facilitate motor behavior changes in isolation or in parallel. The first mechanism is use-dependent motor learning, which depends upon repeated task-specific practice. This is important to the researchers as it is recognized to be a very powerful tool to assist a patient in eliciting functional changes in the central nervous system. Essential to the success of use-dependent motor learning is focus and attention to the task being practiced. The second mechanism is instructive motor learning, which, in the rehabilitation setting, consists of active teaching by a therapist to help the patient correct movement errors or learn correct movement strategies. The fourth mechanism is sensorimotor adaptation, which are changes in motor behavior elicited due to sensory perception errors. In other words, this mechanism is driven in large part by proprioceptive demands which assist the nervous system in the development of novel movement schemas.

The third mechanism, and the one which relates directly to the purpose of the present paper, is reinforcement learning. The researchers define reinforcement learning as "an improvement in motor behavior that is driven by binary outcome-based feedback" (Leech et al., 2022, p. 4). They emphasize that reinforcement learning is dependent upon the patient receiving external feedback about the relative success or failure of a movement attempt. This differs, in a strict sense, from instructive motor learning in that the feedback need not directly tell the learner how to perform a movement. Reinforcement learning, in a basic sense, simply tells the learner whether they performed or are performing the movement correctly.

The researchers explain that reinforcement learning may be tied directly with the basal ganglia and reward-based dopamine signaling. Because reinforcement learning is a reward-based strategy, this connection is likely. The basal ganglia, however, is not the only central nervous system structure which is involved in reinforcement learning, as the primary motor cortex may be involved as well due to evidence of plasticity resulting in this area of the brain due to reinforcement learning. Though the involvement of cognitive processing in reinforcement learning was previously thought to be quite small, the researchers now believe that it is much higher than traditionally believed.

An additional characteristic of reinforcement learning is that it can lead to a sustained improvement in movement behaviors within a single session, and that these improvements may be retained long-term. This, the researchers point out, is an attractive feature of reinforcement learning which may help clinicians develop programs with long-lasting effects on patient movement quality. Not only this, but the researchers also posit that combining reinforcement learning with sensorimotor adaptations and use-dependent motor learning (explained above) may help patients to have improved retention in learning tasks. In conclusion, the researchers state that reinforcement learning may be involved in both the initial stages of learning as well as the associative stage, making clear that it is a very important strategy to use in motor skill development.

Reinforcement Strategies in a Return-to-Duty Protocol

For this hypothetical case study, a number of reinforcement strategies can be employed to assist the soldiers in a successful and holistic rehabilitation program. External reinforcers, or those which will come from the coach, will be utilized, and internal reinforcers, which will come from an intrinsic sense of achievement in the soldiers, will be nurtured. Vicarious reinforcers, which are reinforcers resulting from one seeing another be praised due to correct performance, will be explored. Negative reinforcers, or those which remove an undesired event or outcome, will also be noted. Punishments, which are related to reinforcers, are designed to decrease the occurrence of a certain behavior such as a mistake or a lack of effort (Haff & Triplett, 2016). Three of each of the strategies listed above will be explored in order to offer recommendations that can be utilized in a tactical performance environment.

It is important to note, however, that reinforcement techniques, and the manner in which they are provided, is of immense importance. For example, a coach who is working with young children or middle

schoolers will obviously use a different tone of voice, word choice, and demeanor when providing verbal positive reinforcement than will a coach who works with professional or tactical athletes. In addition, coaches of elite adults will also forgo much of the non-verbal methods of positive reinforcement such as stickers or prizes. However, it may be beneficial to (in a more serious manner) recognize an "athlete of the week" as a mode of positive reinforcement for the athlete who works hardest to master the skill taught.

External reinforcers that can be used in this scenario include the following: verbal praise when correct technique is achieved and demonstrated; fist bumps or high fives after a set in which good effort and technique are demonstrated; and allowing the soldiers to overhear a good report given to a commanding officer from the coach regarding their effort and attention to detail in the technique being learned. Internal reinforcers which the coach can strive to nurture in the soldiers are: encouraging a sense of accomplishment after a good performance, ie. the coach can remind the soldiers to think back over each good set and about how it felt "right"; the coach can remind the soldiers to think about the goals that they set at the outset of their rehabilitation program and how each good repetition helps them build toward full healing; and the coach can encourage the soldiers to see how accomplishing each short-term goal in their plyometric program can be applied to their lives in general, ie. in family and relationships.

Vicarious reinforcement techniques, within this scenario of highly elite performers, could come naturally to such competitive tactical athletes. Examples of this type of reinforcement that could help drive the soldiers to elevated levels of focus and performance are: seeing the other being verbally praised for good technique or effort; noticing the sense of accomplishment that the other has due to a good performance outcome; and noticing a critique from the coach of the other person, which could lead them to work to prevent the error from occurring.

In strength and conditioning scenarios, the conditioning has a purpose and is intentionally included in the program in order to benefit the athlete and elicit beneficial physiological adaptations. For this reason, it may be counterintuitive to remove conditioning as a reward. However, the strength and conditioning coach, when teaching skills such as plyometrics, could still utilize negative reinforcement, but in a much different manner than a sport coach might. For example, the coach could remove certain skill learning drills (which may be boring to the athletes) when all have mastered it, or may allow those who have mastered the skill to move on to a more enjoyable portion of the workout. They feel accomplished and that they have "graduated" from the more mundane drills and can then progress to more enjoyable exercises. In this way, negative

reinforcement is still provided without removing essential components of the training session such as conditioning. Other examples of negative reinforcement that could be used in this scenario are: allowing the soldiers to choose a final conditioning drill of the day (rather than it being decided by the coach) if they exert effort and demonstrate mastery within the training session; and allowing the soldiers to leave training early, forgoing the conditioning portion, if they exert effort and demonstrate mastery within the training session, as long as it does not negatively affect the overall program by omission of a component.

Though punishments are recommended to be used sparingly within the sports sphere (Haff & Triplett, 2016), it is used often in tactical training settings. For this reason, the soldiers in this scenario will be used to it and may possibly respond to it more favorably than the general population. However, especially in a rehabilitation or post-rehabilitation setting, it would be unwise to utilize punishments in the same manner that they are enacted in a context such as infantry school or flight training due to the risk of exacerbating an injury. For this reason, the coach would need to be aware of and mindful of the injury pathology and risk factors for re-injury. With this in mind, punishments in a tactical rehabilitation setting could include: making the soldiers describe their error and how to fix it multiple times if errors were repeated in training; having the soldiers hold an isometric position, such as a plank, that does not aggravate the injury or reduce the effectiveness of the training session; or adding extra conditioning at the end of the session which does not increase the risk factors for re-injury.

Implementing Reinforcement Strategies

When teaching exercises and movement patterns in plyometric programs, it is very important to utilize many of the above reinforcement strategies to help athletes more effectively learn the movement skills and learn why they are being performed. The first step in approaching the scenario of plyometric technique for soldiers who are in a return-to-duty protocol due to an ACL injury would be to work with the soldiers to set clear goals which can help to more effectively learn through reinforcement techniques. Research has demonstrated that a coach or clinician working with athletes in goal-setting helps augment the benefits of goal-setting, compared to the coach or clinician choosing the goals for the athletes (Brinkman et al., 2020, Leech et al., 2022).

While teaching plyometric technique skills, it would be beneficial to utilize external reinforcers each training session. In this way, the soldiers would be aware of not only their success in general, but their success in each movement skill as exercise difficulty progresses. Especially when the soldiers were first learning the takeoff and landing stances, the coach could verbally praise the ones who are holding a correct stance (but with specific praise so that the athletes know what they are doing correctly) saying things such as "Great work with the arm position!" or "Way to load the hips!". If one of them were struggling with form, it is important for the coach to still positively reinforce what they are doing correctly while still teaching how to fix mistakes; for example, the coach could say, "Good job with the foot position! Let's work on the arms by keeping a bend in the elbows....yep, just like that, good!" In this way, instructive motor learning and reinforcement are utilized in parallel.

This also helps to facilitate open communication with their coach, and will make the soldiers more likely to be open to constructive critiques from him. An important component of external, positive reinforcement is that it can assist in creating a training atmosphere wherein athletes and coaches can communicate more effectively, and for this reason, external, positive reinforcers would be utilized whenever it was prudent to do so. Internal reinforcers would also be nurtured each training session. A primary method of nurturing internal reinforcers and intrinsic motivators is to begin each training session with a moment for each soldier to think of their goals and how they can work to make them a reality in the current session. Not only this, but the coach can remind them to bring them to the front of their minds during the session, especially when exercises are difficult or strenuous.

Negative reinforcers. due to the reasons explained above, would be used sparingly in this scenario due to each aspect of the training program being crafted for the single purpose of rehabilitating an injury and preventing re-injury. However, it could help with morale to employ them in an intentional but rare fashion, such as on Fridays. If the coach notices that the soldiers' technique, effort, and level of focus is exceptionally high, omitting certain portions of the training session or ending early could help with morale and lead to higher levels of focus and effort in the succeeding week. Punishments would also be used sparingly, for much the same reasons as negative reinforcement. Though as noted above, the population in the scenario would likely respond favorably to punishments as behavior modification strategies, and so they could be utilized if one was late to a training session or exerting little effort.

Vicarious reinforcers, in this specific scenario, would come naturally to the soldiers due to their innate competitiveness and camaraderie. Since they train constantly to make each other better while still remaining competitive, they would likely see each positive reinforcer aimed at the other, such as verbal praise from the coach, as a call to improve their own technique, effort, or focus. It is prudent to expect that vicarious reinforcement would become a daily part of the return-to-duty protocol in this scenario.

Conclusion

As with any training program, especially in rehabilitation, it is understandable for athletes to have highs and lows, both mentally and as regards physical performance. For this reason, it is imprudent to assume that the soldiers in this scenario would not be confronted with any failures, though with an intentional approach to goal-setting and reinforcement techniques, motivation levels could be kept high throughout the program and in the face of adversities. Reinforcement would not be limited to the training center, as the soldiers could receive positive reinforcement from members of their unit, commanding officers, and family members. This in turn could help the soldiers return to each training session with motivation and focus levels high, leading to improved motor learning and overall outcome in their return-to-duty protocol.

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