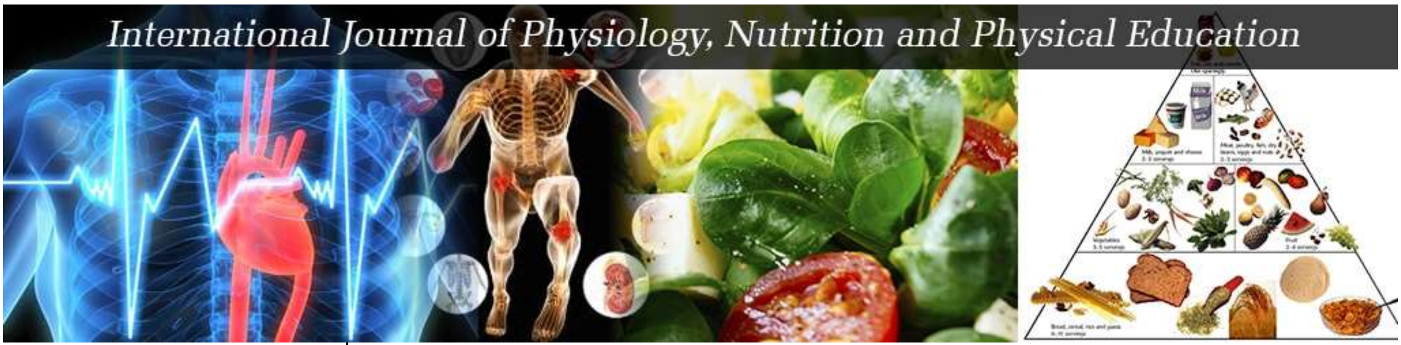

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Incorporating strength and conditioning fundamentals into rehabilitation program

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Abstract
Conditioning and Rehabilitation are sometimes viewed as two distinct processes in the healing of sports injuries. For targeted return to sport training, an athlete often moves from the rehabilitation setting under the supervision of an athletic trainer, physical therapist, or both to the strength and conditioning coach. It's well known that these two aspects of returning to sport have different objectives. Because the period of their application encompasses distinct stages of recovery following an accident, the initial aims of each are frequently different. Post-injury rehabilitation's primary goals are to reduce dysfunction, promote tissue healing, and offer a methodical progression of strength and range of motion. Specific return-to-play objectives are crucial throughout the recovery-to-function stages. While creating and carrying out an athlete's rehabilitation program, a thorough understanding of particular guidelines and program specifications is required. It is imperative that all those providing care for the athlete work together and interact with each other. This study aims to present the data that currently supports the application of training principles in sports recovery and offer recommendations for how these principles may be used at various stages of a planned rehabilitation program.

Keywords: Strength & conditioning, rehabilitation, periodization, strength training, program design

Introduction
It has long been believed that strength and conditioning are exclusively used in the training of healthy athletes, whereas rehabilitation is meant for wounded athletes. Following their recovery from an injury with an athletic trainer, sports physical therapist, or both, athletes frequently go to the strength and conditioning coaches to continue their "weight room workouts" and re-join the team. The strength and conditioning coach creates a programme to prepare the recovering athlete for competition using knowledge of appropriate technique and application of various exercise types in collaboration with the athletic trainer, sports physical therapist, and/or other relevant professionals. There is currently little evidence to justify implementing the concepts of strength and conditioning into such a programme. Numerous writers have looked at post-surgical as well as conservative therapies. Although these studies have all included some particular principles of strength and conditioning, none have used the whole range of strength and conditioning as it relates to the recovering athlete. Therefore, the goal of this clinical commentary is to outline these concepts of strength and conditioning and offer recommendations for using them not only during the return-to-sport phase but also during the whole rehabilitation process.

The rehabilitation program and evaluation of sportsperson
The recovering athlete, their sport, and the established training program principles themselves must all be evaluated for the proper execution of a post-injury rehabilitation program. Sports physical therapists can obtain the knowledge they need to adjust training program variables and accomplish desired results through regular evaluations of the athlete, program, and results. When creating the athlete's program, particular training concepts (Table 1) should be taken into consideration. When putting such a programme into place, the sports physical therapy professional should take the athlete's current stage of recuperation into account. When designing the particular program parameters such as power, strength, endurance, and hypertrophy must also be thoroughly taken into account and targeted.

Table 1: Principles for designing Training Program.

Principle	Definition
Progressive Overload	Explains that when the body develops the capacity to produce more force, strength, or endurance, stress on the system must be gradually increased in order to maintain development in a workout program. According to the concept of specificity, the body obtains benefits from training and exercise based on the type of training it receives. The athlete will perform according to how they train.
Individuality	Recognising all athletes as individuals and creating a training regimen just for them. When creating a resistance training program, it's important to take into account a number of variables, such as age, sex, medical history, prior training experience, injury history, general health, training objectives, motivation, and any recovery limitations resulting from surgery or injury.
Intensity and Volume	Volume is the total weight lifted during an exercise session. The load or intensity of an exercise program is the weight that has been allocated to it. Intensity and volume have an inverse relationship.
Frequency	The quantity of training sessions held during a given time period (Usually listed weekly).
Resistance Type	The four main types of resistance that an athlete can use are: machine resistance (Which increases stabilisation for strengthening isolated muscles), aquatic resistance (Which provides multi-planar resistance with liquid resistance/assistance based on position), free weight and elastic resistance (Which allows multi-planar, whole body movements for motion resistance training), and isokinetic resistance (Which delivers supporting resistance with large amounts of valid and reliable data).
Rest Period	The amount of rest period between workouts and sets. The length of the athlete's rest depends on the type of sport they play, the training objective (Strength, power, endurance, or hypertrophy), the load they lift, and their current state of fitness.
Periodization	The deliberate adjustment of training factors (Repetition, load, and sets) to optimise training adaptations and avoid the condition of overtraining.
Specificity Types	**Energy:** Training the required energy system. **Muscle Action:** Improved strength is somewhat dependent on the kind of muscular activity (e.g., isometric, concentric/eccentric, isokinetic) that is performed during training. **Muscle Group:** Only those group of specific muscle or joints are trained that are to be used according to their particular sport. **Velocity:** Training benefits are particular to the pace at which activities are carried out. Exercise choice and performance specificity order.
Linear Model	Low intensity and a large initial training load define this model. Volume steadily drops and intensity gradually rises throughout training as a result of shifting exercise load and volume throughout a number of predictable mesocycle. The 12-month program is called a macro cycle, with two sub-programs: the micro cycle (1-4 weeks) and the mesocycle (3-5 months).
Non-Linear Model	The foundation of non-linear periodization (NP) is the idea that volume and load should be changed on a regular basis (daily, weekly, or bi-weekly) to provide the neuromuscular system more opportunities for recuperation. Phases are significantly shorter and offer more frequent stimulus changes, which may be quite helpful for building strength.
Reverse	This paradigm is the opposite of the linear model, where volume is initially at its lowest point and intensity is at its maximum one.

The best way to adjust the training variables during the programme depends on knowing the specifications or needs of the particular sport. To best simulate the demands of the sport, preparing for a football lineman in the later stages of recovery should, for example, emphasise explosive power in exercises completed in 7-10 seconds with 20-60 seconds of recovery time. Early on in the rehabilitation process, it could be essential to address some deficiencies that could lead to injury, such as muscular imbalances. It is possible to determine if a recovering athlete is incapable of doing a certain task using a variety of methods (Self-report, damage based, bio-psycho-social, and/or performance-focused assessments). Since an individual's capacity for appropriate functioning is a continuum, it should take into account a variety of factors. A subjective report on functional capacity, analysis and observation of impairments, and functional efficiency testing, where appropriate, should all be part of the evaluation continuum. Functional performance testing has been previously defined as employing a range of physical skills and assessments to ascertain an individual's capacity to engage in sport, occupation, or recreation at the desired level. Also, to safely and promptly resume participation without functional limitations, as well as their capacity to move through up to three planes of movement.

Unconventional (Beyond hand-held muscle and range-of-motion testing) methods are used to evaluate functional performance. These methods offer qualitative and quantitative data on specialised motions used in sports, exercise, and jobs. The success of the adopted programme may be evaluated, in addition to the recuperating athlete and their sport needs, by using the complete evaluation technique. Testing may reveal shortcomings in a particular programme parameter or parameters (Such as functional motion, power, agility, endurance, and/or hypertrophy) in the recovering athlete. In these cases, the programme may be adjusted to address the shortfalls. It would be necessary to address limitations found in basic movement patterns before focusing on power development. Given the current suggestion that evaluating a person's total functional capacity is a multifaceted process, a full explanation of functional evaluation is outside the purview of this clinical commentary. The reader is directed elsewhere for more recommendations about the application of the athlete assessment.

Conventional training program rules

It is crucial to target a muscle or set of muscles for specific training in order to improve endurance, strength, power, and muscle hypertrophy. It is also outside the purview of this discussion, so the reader is urged to contact other sources for comprehensive details on training for these requirements. We'll talk about general parameters here.

It is necessary to create distinct programs and prescribe separate exercises when training for muscular performance, which includes strength, power, and endurance (Table 2). Strength training usually entails doing one to six repetitions at a load/intensity of 80-100% of the maximal weight that the person can lift in a single repetition (1 RM). On the other side, power training necessitates movement velocity as a main factor.

Table 2: Maximum Range for Repetition.

Required Parameter for Training	Repetition Range
Power and Strength	0-6
High level Endurance which is far above Power and Strength	6-12
Low level Endurance which is better than High level Endurance	12-20
Low level Endurance	20-30

While the training components for strength and power exercises may be identical, endurance training is rather different. High repetitions with small weights are a prominent structure in endurance training, which can entail a variety of techniques, such as circuit training. Of the three main indicators of muscle performance, the comparative work-to-rest ratio is the lowest. Since hypertrophy training calls for modest weights and a repetition range of 8-12, endurance training may be used to attain this goal.

Stages of rehabilitation for players post-injury

Immediate Rehabilitation: Accompanied by pain and inflammation in the tissues and/or joints, a decrease in muscular function, detraining, immobilisation risk (depending on damage), and the start of tissue regeneration and/or repair. Preserving the integrity of the affected tissue, restoring range-of-motion (ROM) within bounds, reducing pain and inflammation, and avoiding muscle inhibition are the main objectives to be tackled during this phase. The following are important requirements for moving on to Stage II: ROM of at least 75% on the non-involved (NI) side, minimal discomfort with all phase I activities, and appropriate muscle firing patterns for starting movements.

Intermediate Rehabilitation: Consisting of enhanced muscular function, reduced inflammation, greater utilisation of the affected part of the body or region, and ongoing tissue regeneration or repair. Stage II will focus on two main objectives: maintaining the integrity of the affected tissue or structures and restoring the affected bodily part or region's function. Nearly complete range of motion, muscle length, and joint play, as well as 60% strength of the major engaged musculature in comparison to the undamaged side, are requirements for moving on to Stage III.

Advanced Rehabilitation: Marked by the return of normal joint kinematics, range of motion, and ongoing muscle performance enhancement. Restoring muscular strength and endurance, cardiovascular endurance, and neuromuscular control, balance, and awareness of position are the main objectives to be met during this period. Stage IV requirements include demonstrating the first agility drills with correct form (e.g., avoiding medial break down of bilateral lower extremities, coordinating and symmetrical motion of all areas of the body, controlled movement and having strength > 70-80% of the non-involved (NI) side.

Return to Normal Functioning: Marked by pursuits aimed at restoring the athlete's maximum potential. Preventing re-injury and successfully returning to the athlete's prior ability to perform in their favourite activity are the main objectives to be targeted during this period. Sport-related abilities at competitive levels advanced to regular practice and, eventually, back to elite status.

Creating training program for injured players requires proper analysis

A needs assessment should be carried out in order to appropriately create a rehabilitation program tailored to the patient and their sport. When creating the program, a thorough examination is needed, looking into things like the physiological and biomechanical demands of a sport. A requirements analysis has several components, such as a general biomechanical assessment of the sport that the recovering athlete plays, an examination of the energy sources used in the activity, and a study of the typical injury locations and sequences for the sport. Moreover, a suitable physiological assessment enables the physician to create a plan that targets the precise strength, speed, power, flexibility, and endurance, needed for a particular activity.

To select training exercises that help the athlete grow in a way that is unique to the sport, a biomechanical study is therefore necessary. Programs for resistance and functional training both rely on specificity in training. According to the authors, in order to make sure that preventative techniques are used, the sports rehabilitation professional should be knowledgeable of the injury patterns that are typical of the sport in which the recovering athlete competes. For instance, compared to athletes who play other sports, female football and basketball players have shown a greater incidence of anterior cruciate ligament ruptures. Similar to players in other sports, American football linemen and gymnasts have a higher chance of developing spondylolisthesis and spondylolysis. Each of these instances demonstrates how customised training plans should be created for recovering athletes in order to meet their unique demands and optimise performance while preventing further damage. Table 3 provides an example of these ideas for the reader.

Table 3: ACL reconstruction surgery recovery for a male football player and a female soccer player are compared in this assessment.

Analysis of sport	Football	SOCCER
Analysis of Biomechanics	Explosive moves with multiple joints and directions that change depending on the posture. It involves several pauses and starts.	Motions in several directions at different intensities that frequently call for simultaneous ball managing. Synchronisation between the feet and eyes.
Physiological assessment for energy needs	ATP has the primary role here. Optimum strength and power, flexibility, and balance. Only one match in a week is required. Acclimatizing to the environment.	Aerobic System is primary. Endurance, Flexibility, Balance and Strength. Several matches can be played in a week. Consideration about the Female athlete triad and acclimatizing to the environment.
Injury Patterns	Muscle strains and ligament sprains are some examples of soft tissue injuries. Spondylolisthesis and Concussion are more common in linemen.	In soccer, women's chances of ACL injuries is higher. Strains and sprains are some examples of soft tissue injuries. Overuse of tendinopathies Spondylolysis

Evaluating the strengths and shortcomings of each recovering athlete can be a challenging task. As was already said, determining an athlete's ability to function accurately requires taking into account a variety of factors. It is necessary to evaluate the recuperating athlete's strengths and limitations in addition to learning about their training history, injury history, and fundamental physical attributes. The length of time spent playing the sport, the amount of time spent specialising in it (or a particular position within it), and the degree of competitiveness the athlete is used to competing at may all have an impact on their training status.

Designing the rehabilitation program

Adjustment of the program principles is the next phase in developing the rehabilitation program once the physician has identified the demands of the recuperating athlete. As previously stated, this article cannot cover every requirement for program design; nonetheless, a discussion of these concepts is necessary, particularly given the dearth of research on their use in the context of recovering athletes. Sports physical therapists are interested in manipulating the following program principles: resistance/training load, workout selection, availability of training machinery, frequency of training, exercise sequence, and rest interval.

Selecting the Exercise: The physician should take into consideration the substantial treatment aspect of exercise selection. Exercises that work many muscle groups at once are referred to as multi-joint exercises. Squats, overhead presses, cleans, bench presses, and push-ups are a few multi-joint workouts. Since these exercises are the most taxing on the body and are the ones that are most advised for building muscle and bone strength, they are often performed first in the course of training. Supplementary, or isolation, exercises are the other kind of exercise. Knee extensions, lateral raises, and forward raises are a few types of isolated workouts. These isolation exercises are a suitable option for the untrained or novice athlete, as they are essentially single joint, single plane workouts. In the end, though, an effective program for an experienced athlete ought to involve various multi-joint workouts.

As an athlete advances to multi-joint activities, they will get more training and have more practice time to develop the coordination needed to do the exercise correctly and safely. Large muscular mass, multi-joint activities have been demonstrated to significantly increase anabolic hormone levels early in the training regimen. Smaller muscles (such as those in the impacted region) may be more susceptible to this kind of anabolic response compared to when small muscle activities are the sole thing done.

Training Equipment Availability: Certain workouts cannot be performed or must be modified due to a lack of equipment. Lack of surface or overhead space might make it difficult to do movements with free weights that entail dropping or pushing weights upwards. For instance, bumper plates that rebound on the ground are used for a lot of Olympic lifts that are performed overhead (Such as snatch jerks) in order to increase athlete safety in situations in which a lift is missed or a maximum lift is attempted. The bar is frequently dropped to the ground in any of these situations, where it rebounds and could hurt someone else. For the recuperating athlete, certain machines might not be multidimensional enough to be sport-specific, therefore, the therapist will need to add suitable exercises to training regimens. For instance, using a dumbbell or barbell bench press rather than a weight machine would be preferred when the recovering athlete wants to do a chest press action. In contrast to a sitting chest press using a weight machine, which has one axis of movement, these exercises use the same muscles but compel the athlete to make modifications in order to complete the lift since the axis of motion is not fixed.

Frequency of Workout: Exercise regularity is ultimately determined by the volume and load of the workouts, the predominant movement type (multi vs. single joint), the athlete's training level, and their fitness objectives. Resistance exercise is often advised in the early phases of training to guarantee recuperation on alternate days; however, as experience increases, the frequency of training may rise. If the volume is maintained, previous researchers have shown little variation in the strength improvements seen while exercising one, two, three, or five days per week. Extended recovery time is recommended when using near maximum resistances. The physical therapist should make sure that the athlete is participating in other concurrent training programs as well. In order to guarantee that the athlete gets the right rest and recuperation, the training frequency may need to be adjusted to fit their schedule. Likewise, if the athlete seems to be hitting a plateau or only making small improvements in one or more training parameters (e.g. strength, power, endurance), then increasing the frequency of training could be necessary.

Systematic Sequencing of Workout: The right sequencing of exercises is essential for achieving the optimal load and volume for every workout. The sports physical therapist must meticulously plan in order to integrate isolated strengthening exercises with multi-joint activities in a planned way. When creating the training regimen, the physical state of each athlete, as well as their specific strengths and limitations, must be taken into account. There will be a description of several ways to use the workout order. It is recommended that multi-joint exercises be done first in the workout session since they demand the highest levels of coordination, ability, and energy. For instance, you should do the bench press before the triceps extensions.

Given that multi-joint raises are the most taxing, an athlete who has already exhausted their smaller muscle groups from prior workouts is unlikely to get the most out of these exercises. A training method called pre-exhaustion involves isolating a muscle in a single-joint, single action before executing the identical muscle workout on multiple joints. Leg curls or leg extensions done before a back squat or deadlift are a type of pre-exhaustion exercise. This method may be used by the sports physical therapist to help reduce the impacts of training monotony or if they believe that the multi-joint motions are not fully developing the muscles in concern.

Exercises may be paired in a variety of ways to test the athlete, break up the monotony, and highlight muscular growth and endurance. In the ultimate setting, workouts alternate between both agonists and antagonists, with little to no rest in between. Super sets, for instance, might be, a bench press accompanied by a seated row or a biceps curl subsequently followed by a triceps pushdown. The compound setup involves alternating between two distinct workouts for the same muscle group, with little to no rest in between. Compound settings include movements like barbell bicep curls accompanied by alternating dumbbell curls or anterior lunges before ending the session with squats. Early in their training, athletes in low physical condition could find enormous settings, compound settings, or pre-exhaustion procedures excessively demanding. Another way to change the sequence in which an athlete trains is to have them alternate between both upper and lower body activities. The athlete may also be asked to alternate between upper body push and lower-body pull exercises, or the other way around, by the physician. The athlete can also execute a "push-pull" routine. The athlete can do a front squat and a deadlift in this position. In addition to agonists and antagonists, push-pull exercises can also incorporate an upper body "push" exercise combined with a lower body "pull," or the opposite. Taken together, these techniques enable additional workouts to be performed in a session and allow for greater effort in each exercise since they prolong the recovery of each targeted muscle group.

Training Load and Rest Period: The recovering athlete may modify all of the aforementioned training factors, but doing so will require that the sports physical therapy professional create athlete-specific programs while keeping the previous suggestions in mind. It is recommended that an athlete recuperate for at least 24 hours after a session, and for 48 hours after a workout involving the same muscle group, regardless of the kind of injury. For a recovering athlete who sees the trainer just once or twice a week, a full body workout is recommended to optimise training balance. The sport of the recovering athlete and the portion of the body or region to be trained must be carefully taken into account when calculating the training load and rest ratios. For instance, the majority of the muscles in the trunk are slow-twitch type I muscle fibres, which means that training should focus on high repetitions with low load endurance. Other, more powerful muscles used in leaping, such as the quadriceps and gastrocnemius, need to be trained using strength-based regimens that graduate to lighter weights and faster rates, as well as plyometric workouts for increasing power.

In strength and conditioning, one rep max testing is typically used to estimate training load. Because 1RM testing necessitates a methodical, incremental development in the highest load lifting capability, it is frequently detrimental to recuperating athletes. For these athletes, using training load charts and 1 RM estimation is advised, even if this approach is the most efficient and precise. The De Lorme methodology, the Daily Adjusted Progressive Resistance Exercise (DAPRE) technique, and the OMNI-RES method are further approaches for estimating training load.

Table 4 provides an example of certain resting parameters that are to be applied by the training coach during the rehabilitation program.

Table 4: Different Parameters designed for Rest Period.

Basic parametres obtained	rest period
Muscular Power	6-8 minutes
Maximum Muscle Strength	3-5 minutes
Hypertrophy of the Muscle	2-3 minutes
Muscular Endurance	40-60 seconds

Unless the athlete has established the neuromuscular capacities necessary to safely and efficiently test with greater loads in order to more precisely identify their 1RM, these tables are meant to be used as a point of reference. These types of tables are only one way to calculate load; there are other, more successful ways as well. The average number of reps per set, sets per session, and sessions per week are commonly used to dictate training volume. It has previously been shown that training volume is crucial for achieving maximum strength and hypertrophy improvements in the early stages of resistance training. The results indicated that maximum strength improvements occurred in untrained, average people at a mean training level of ≈12 RM, whereas trained individuals showed similar gains at a mean training frequency of ≈8 RM. The training objective, the amount of load lifted, the sport the athlete plays, and the athlete's current training state all influence how long the rest time should last. Because the duration of the rest interval is directly correlated with the weight lifted, it serves as a major factor in determining the total intensity of an exercise session. The duration of the recovery phase influences the amount of adenosine triphosphate-phosphocreatine (ATP-PCr) that is restored as well as the rise in blood lactate concentrations that occurs after exercise.

Combining exercise fundamentals and rehabilitation guidelines into an injured athlete's program

Based on current research and principles utilised with fully fit athletes, the preceding sections provided recommendations on various factors and the potential for their adjustment of these principles of training for the rehabilitative athlete. Furthermore, periodization is defined in **Table 1**, along with the distinctions between linear and non-linear periodization. Regarding the damaged body component, the recuperating athlete could first need to be seen similarly to the untrained group. The damaged body part or area should be the prime focus for improvement, and that can be achieved with more reps and attaining muscular endurance/hypertrophy during the very first non-linear periodization phase, followed by the start of strength and conditioning later on. More advancement into extended strength and power training should be included as the patient makes greater progress in their recovery. Non-linear periodization gives the physician the opportunity to train many parameters simultaneously, while still focusing on one during a certain phase. This is in contrast to linear periodization, which emphasises just one variable (Endurance, hypertrophy, or strength).

Short term linear periodization might be used to build a rehabilitation program as an alternative to the previously mentioned non-linear periodization. A short-term linear program would call for a high volume, low-intensity beginning phase (Endurance and/or muscle growth phase). At the completion of rehabilitation, an advancement into the strength/power mode and ultimately the power phase would take place. The author of this article believes that because non-linear periodization allows for the integration of several factors into the various stages of the rehab program, it may end up being a more beneficial approach to program design for the recovering athlete.

Conclusion

Any rehabilitation program must be customised and decision-made with consideration for the principles of strength and conditioning as well as coaching criteria. This is particularly crucial for an injured athlete's recovery and complete return to function. When executing such programs, the sports therapy professional should be aware of all the elements and factors that go into an athlete's rehabilitation program. The incorporation of strength and conditioning ideas into the rehabilitation of injured athletes is currently the subject of little literature. Though obvious for best practices, the efficacy of incorporating these training methods into an injured athlete's recovery is still ambiguous.

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