Do Single Joint Exercises Enhance Functional Fitness?

Brad Schoenfeld, MSc, CSCS

Bret Contreras, MA, CSCS

Abstract

Functional training programs typically focus on multi-joint movements. However, functional transfer exists on a continuum, where different exercises impart varying degrees of functional improvements depending on the particular demands of the task. This paper will discuss the potential role of single joint movements in functional training program design.

Training for functional fitness has become an increasingly popular approach for personal trainers and strength coaches alike. According to Okada et al. (2011), functional movement can be defined as the ability to produce and maintain a balance between mobility and stability along a kinetic chain while carrying out fundamental patterns with accuracy and efficiency. Given this definition, the primary goal of functional training is to optimize the ability for individuals to carry out activities of daily living, recreational pursuits, and/or sports performance (Beckham and Harper, 2010).

A common tenet amongst functional fitness practitioners is that movement patterns should be trained as opposed to individual muscle groups. Hence, functional training programs typically focus on multi-joint movements carried out in a multi-planar environment. Since single-joint exercises are rarely performed as part of daily activities or sport actions, they are often dismissed as "non-functional" and therefore excluded from functional program design (Beckham and Harper, 2010).

There is substantial evidence to support the use of multi-joint movements as a means to improve functional ability (Beckham and Harper, 2010). Positive transfer is best achieved when specific muscle activation patterns reinforced through training are similar to those required in the alternative task (Carson, 2006). Conceivably, a greater association between movement similarities results in retaining relevant firing patterns and discarding irrelevant patterns, thereby strengthening the desired movement pattern (Carson, 2006). A substantial degree of task specificity has been found to occur in response to strength training adaptations, with multi-joint movements showing the greatest applicability to activities of daily living (Kraemer et al. 2002; Kraemer & Ratamess 2004).

It can be misguided, however, to view exercises simply as "functional" or "non-functional." Rather, functional transfer exists on a continuum, where different exercises impart varying degrees of functional improvements depending on the particular demands of the task (Schoenfeld, 2010). Conceivably, performing a combination of exercises along this continuum may produce a synergistic effect on functional transfer, improving an individual's ability to carry out desired tasks. The purpose of this paper will be to discuss the potential role of single joint movements in functional training program design.

Single-Joint Exercises in Functional Training

Although multi-joint movements better simulate performance of specific activities, they tend to favor certain muscle groups at the expense of others. This may lead to muscle imbalances, which potentially can hasten the onset of injuries and impair the optimal performance of other tasks. For this reason, an optimal program should utilize "core program exercises" as the backbone of the program consisting of multi-joint and multi-muscle movements, in addition to "assistant exercises" consisting of targeted movements, which provide balance to the program and increase the program’s overall efficacy. For example, during performance of the squat, the hamstrings have been shown to produce only half the electromyographic activity as that of the leg curl and stiff legged deadlift (Wright et al. 1999). This is consistent with the bi-articular structure of the hamstrings, which allows the muscle complex to function both as hip extensors and knee flexors. Thus, hamstrings length remains fairly constant throughout performance of multi-joint exercises that require simultaneous hip and knee extension. Weak hamstrings may be associated with greater risk of lower body injury (Orchard et al. 1997; Croiser et al. 2008), possibly as a result of decreased muscle co-activation (Baratta et al. 1988). Hence, single-joint exercises that directly target the hamstrings may be beneficial to optimize functional development of the muscle (Wright et al. 1999). While it is true that most sport actions are multiple joint in nature, the same principle described above holds true for sports; imbalances may be created from sport participation which needs to be addressed in the athletes' programming in order to provide structural balance.

Similarly, multi-joint upper body exercises may fail to optimally work the upper arm musculature due to disadvantageous length/tension relationships (Sakurai, et al, 1998; Basmajian and Latif, 1957). For example, in the start position of a chin-up (hanging from the bar with arms straight), the biceps are in a fully lengthened position at the elbow joint while maximally shortened at the shoulder joint. During dynamic movement these aspects reverse so that the biceps shorten at the elbow while lengthening at the shoulder. Thus, there is little functional change in muscle length throughout the range of movement, thereby limiting force output. In the same way, the optimal length-tension relationship of the long head of the triceps occurs when the shoulder joint is flexed to approximately 180 degrees (Le Bozec, et al, 1980). Since shoulder joint position changes throughout the range of motion during performance of multi-joint pushing exercises such as the bench press and push-up, these movements fail to promote complete development of the long head of the triceps. Performing single-joint arm exercises allow the muscles to be trained at their optimal length, increasing upper body strength and potentially improving the ability to carry out functional tasks.

Conversely, single-joint exercises can be employed to bring about active insufficiency--the condition where a two-joint muscle is shortened at one joint while a muscular contraction is initiated by the other joint. Because of the weak contractile force of a muscle when its attachments are close together, the muscle is at its lowest point on the length-tension curve and therefore its capacity to produce force is diminished. Trainers and strength coaches can utilize this concept to target muscle imbalances. For example, when training the plantarflexors of the ankle joint, performing calf raises with knees bent will cause the gastrocnemius to become slack, thereby shifting the majority of work to the soleus (Kawakami et al. 1998). Given that the soleus has been shown to produce more mechanical work than the gastrocnemius in a countermovement jump, this may justify an assistant exercise that targets the soleus if increased countermovement jump height is sought (Nagano et al. 2005).

The ability for single-joint exercises to favorably affect length-tension relationships has implications beyond simply enhancing muscle development. Single joint movements such as seated leg curls, incline arm curls, and overhead triceps extensions place the hamstrings, biceps brachii, and long head of the triceps brachii, respectively, into a position that exceeds resting length, allowing them to be trained while actively stretched (Schoenfeld, 2002). Leonard and Herzog (2010) found that when activated muscle fibers were stretched to the point where no cross bridges remained, titin stiffness contributed significantly to passive tension, thereby protecting against eccentric damage. The authors theorized that titin actually binds to actin which increases the tension on the unbound titin filaments. This increased stiffness can promote greater functional benefits through increased reactive strength and enhanced joint stability. For example, the soccer throw-in, baseball pitch and throw, and volleyball spike all involve overhead elbow flexion. Hence, athletes in each of these sports may directly benefit from the inclusion of overhead triceps extensions to target the long head of the triceps.

Training at long muscle lengths also can enhance tendon stiffness, thereby increasing muscle activation through a full range of joint motion. Kubo et al. (2006) showed that isometric leg extensions at long muscle lengths (ie: 100 degrees of knee flexion) resulted in greater increases in tendon stiffness than isometric leg extensions at shorter muscle lengths (ie: 50 degrees of knee flexion). These adaptations were accompanied by significant increases in maximal voluntary contraction (MVC) at all joint ranges, whereas training at short muscle lengths only showed increases in MVC at or near the specific training angle.

Moreover, training at long muscle lengths during single joint exercises can increase the optimum length at which muscles produce peak force as evidenced by a shift in the peak torque angle curve. Aquino et al. (2010) found that performing seated leg curls improved stretch tolerance in those with tight hamstrings. These results were attributed to an increase in fascicle length via addition of sarcomeres in series as no change in hamstrings flexibility was observed. Augmenting the optimal length of a muscle has both injury prevention and enhanced performance implications.

Single joint training can be used to mimic sport specific actions and vectors which can improve power production. For example, the four-way hip machine can be used to mimic the action of the hips during sprinting. Given that Guskiewicz et al. (1993) showed a strong relationship between hip flexion and hip extension strength and sprint speed as measured on a four-way hip machine, it makes sense to perform targeted training for the hip musculature if speed improvements are sought.

Finally, single joint exercises can be used to increase the relative contribution of a particular muscle toward a particular multi-joint movement pattern. For example, increasing gluteal activation through simple low-load activation drills (such as a bodyweight glute bridge) has been shown to increase hip extension strength and hamstring flexibility while decreasing the incidents of hamstring cramping (Wagner et al. 2010). The researchers theorized that their protocol increased gluteal activation during running; thereby relieving the hamstrings and preventing overuse and fatigue-related cramping. Strengthening certain muscles such as the gluteus maximus, psoas, serratus anterior, rotator cuff, and mid/low trapezius through targeted single joint training may provide a valuable "prehab" effect and thus decrease the likelihood of injury.

Conclusion

Exercise selection should not be viewed as an either/or decision. While the principle of specificity dictates that multi-joint movements should comprise the basis of functional training programs, evidence suggests that single joint exercise can also play an important additive role. Augmenting traditional functional training programs with single joint exercises can promote synergistic improvements in muscle strength that ultimately transfer into increased performance of daily activities and sports performance, over and above that which can be achieved with multi-joint training alone.

References

1. Aquino CF, Fonseca ST, Goncalves GGP, Silva PLP, Ocarino JM, Mancini MC. Stretching versus strength training in lengthened position in subjects with tight hamstring muscles: A randomized controlled trial. *Manual Therapy.* 15(1) 26-31, 2010.
2. Baratta R, Solomonow M, Zhou BH, Letson D, Chuinard R, D'Ambrosia R. Muscular coactivation: the role of the antagonist musculature in maintaining knee stability. Am J Sports Med, 16:113–122, 1988.
3. Basmajian JV, Latif A. Integrated actions and functions of the chief flexors of the elbow. J Bone Joint Surg [39-A]. 5:1106—1117, 1957.
4. Beckham S, Harper M. Functional training: Fad or here to stay? ACSM's Health & Fitness Journal, 14(6):24-30, 2010.

5. Carson RG. Changes in muscle coordination with training. J Appl Physiol, 101(5):1506-13, 2006.
6. Croisier JL, Ganteaume S, Binet J, Genty M, Ferret JM. Strength imbalances and prevention of hamstring injury in professional soccer players: a prospective study. Am J Sports Med,36(8):1469-75, 2008.
7. Guskiewicz, K., S. Lephart, and R. Burkholder. "The Relationship Between Sprint Speed and Hip Flexion/Extension Strength in Collegiate Athletes." *Isokinetics and Exercise Science*. 3, 111–116, 1993.
8. Kawakami Y, Ichinose Y, Fukunaga T. Architectural and functional features of human triceps surae muscles during contraction. J Appl Physiol, 85(2):398-404, 1998.
9. Kraemer WJ, Adams K, Cafarelli E, Dudley GA, Dooly C, Feigenbaum, MS, Fleck SJ, Franklin B, Fry AC, HoVman JR, Newton RU, Potteiger J, Stone MH, Ratamess NA, Triplett-McBride T. American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. Med Sci Sports Exerc, 34:364–380, 2002.
10. Kraemer WJ, Ratamess NA. Fundamentals of resistance training: progression and exercise prescription. Med Sci Sports Exerc 36:674–688, 2004.
11. Kubo K**,** Ohgo K, Takeishi R, Yoshinaga K, Tsunoda N, Kanehisa H, Fukunaga T. Effects of isometric training at different knee angles on the muscle-tendon complex in vivo. *Scand J Med Sci Sports* 16: 159–167, 2006.
12. Le Bozec, S., B. Maton, and J.C. Cnockaert. The synergy of elbow extensor muscles during dynamic work in man. I. Elbow extension. Eur. J. Appl. Physiol. 44:255—269. 1980.
13. Leonard TR and Herzog W. Regulation of muscle force in the absence of actin-myosin-based cross-bridge interaction. *Am J Physiol Cell Physiol*. 299: C14-C20, 2010.
14. Nagano A, Komura T, Fukashiro S, Himeno R. Force, work and power output of lower limb muscles during human maximal-effort countermovement jumping. *Journal of Electromyography and Kinesiology*. 15:367-76, 2005.
15. Okada, T, Huxel, KC, and Nesser, TW. Relationship between core stability, functional movement, and performance. J Strength Cond Res. 25(1): 252-261, 2011.
16. Orchard, J., J. Marsden, S. Lord, and Garlick, D. Preseason hamstring muscle weakness associated with hamstring muscle injury in Australian footballers. *Am. J. Sports Med.* 25:81–85, 1997.
17. Sakurai G, Ozaki J, Tomita Y, Nishimoto K, Tamai S. Electromyographic analysis of shoulder joint function of the biceps brachii muscle during isometric contraction. Clin Orthop Relat Res. 354:123-31, 1998.
18. Schoenfeld, B. Accentuating muscular development through active insufficiency and passive tension. Strength and Conditioning Journal, 24(4), 20-22, 2002.
19. Schoenfeld, B. (2010). Is functional training really functional? *ACSM Certified News. 20(3)*, 5-6, 2010.
20. Wagner T, Behnia N, Ancheta WKL, Shen R, Farrokhi S, Powers CM. Strengthening and neuromuscular reeducation of the gluteus maximus in a triathlete with exercise-associated cramping of the hamstrings. *Journal of Orthopaedic & Sports Physical Therapy.* 40(2) 112-19, 2010.
21. Wright, GA, TH DeLong, and G. Gehlsen. Electromyographic activity of the hamstrings during performance of the leg curl, stiff-leg deadlift and back squat movements. J. Strength Cond. Res. 13:168–174. 1999.