Transfer Between Lifts: Increased Strength in Untrained Exercises

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ABSTRACT

The principle of specificity confers that physiological adaptations to exercise reflect the specific stimuli applied during an exercise training program. When applied to resistance training (RT), the principle of specificity implies that the acquisition of strength, which is often measured as a 1 repetition maximum, is specific to several variables of an RT program such as intensity, contraction type, and motor pattern. Although the principle of specificity holds true, a phenomenon called "transfer" also occurs when a lifter increases their strength in an exercise that they did not train. For example, if a lifter performed lunges in lieu of back squat, but their back squat strength increased anyway, there would be transfer between the lunge and back squat. This column summarizes recent research that reported transfer between bilateral exercises, unilateral to bilateral exercises, and single-joint to multiple-joint exercises and provides several recommendations for practical applications along the way.

INTRODUCTION: SPECIFICITY AND TRANSFERABILITY

The principle of specificity confers that physiological adaptations to exercise are specific to the stress applied to the body during a training program (3,10). As it pertains to resistance training (RT), specificity is exemplified by the notion that low-intensity, high-repetition training (30–50% 1 repetition maximum [1RM], 25–35 reps) stimulates superior increases in muscular endurance (16,24), whereas high-intensity, low-repetition training (85–95% 1RM, 2–4 reps) is a more viable program to increase muscular strength (23,24). Moreover, the acquisition of strength, which is commonly measured as a 1RM, is specific to several variables that include intensity (11), repetition range (24), contraction type (28), joint angles (27), and training modality (12). Understanding the principle of specificity is important for strength and conditioning specialists (SCSs) because they must consider the motor patterns and power demands of their sport when selecting exercises that will transfer best to athletic performance (29). Indeed, transfer has traditionally been studied within the context of determining how or if a specific RT movement, such as a back squat, will have a beneficial effect on an athletic movement such as sprinting or jumping (6,19). It has been proposed by some (6,19) that the transfer between RT exercises and sports skills depends on the angle of force vector application, as exercises that apply anteroposterior forces to the body (e.g., hip thrust) have a more positive effect on skills that involve horizontal force production and acceleration (e.g., sprinting). Contrarily, axial-loaded exercises that apply vertical forces to the body (e.g., front squat) may have a more useful effect on skills that involve vertical force production, such as jumping (6,19).

On a different note, recent research has assessed whether there is transfer between common lower-body RT exercises (1,6,17,26), which manifests as an increase in maximal strength in an untrained exercise. In other words, if a lifter performs kettlebell swings for a block of training without performing a deadlift (DL), but their DL 1RM increases as a result of the kettlebell swing, there would be transfer between the exercises (14) (Figure 1). Information like this is important because it will allow SCSs to diversify their RT programs and to cycle through exercises that have constructive, residual effects on each other (e.g., a block of split squat [SQ] training may improve back SQ performance). In fact, as opposed to a fixed-exercise regimen, some have reported that providing a variety of lifts for the same muscle group increases perception of motivation (4), volume performed (21), and upper-body strength (21). Furthermore, transfer and specificity have recently been assessed by comparing the effects of single- versus multiple-joint (MJ) exercises (5,7,18,27) and machine versus free-weight exercises (20,22,25,28) on hypertrophy and strength. Thus, whether an SCS wants to improve an athlete's vertical jump height (VJH), a powerlifter's

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Figure 1. An example of transferability between 2 bilateral lower-body exercises (e.g., deadlift and kettlebell swing) as demonstrated by Maulit et al. (14). The subjects in the kettlebell swing group increased their deadlift 1RM by 8 kg despite not performing the deadlift during the four-week mesocycle of training. 1RM = 1 repetition maximum.

1RM back SQ, or the adherence/motivation of a general population client, specificity and transferability have a profound influence on exercise selection. In turn, this article will summarize recent research that has measured the transferability between the following types of exercises: bilateral to bilateral, unilateral to bilateral, single joint to multiple joint, and machine to free weight.

TRANSFER BETWEEN BILATERAL MULTIPLE-JOINT LIFTS

Recently, the barbell hip thrust has emerged as a hip-extension exercise that can be used as a supplementary lift for more traditional lower-body lifts such as SQ or DL. To assess the transfer between hip thrusts and front SQ, Contreras et al. (6) recruited 28 resistance-trained adolescent athletes (aged 14–17 years) and randomly assigned them to hip thrust (n = 14) or front SQ (n = 14). After 6 weeks of training, data indicated that both groups increased their 3RM for front SQ and hip thrust, meaning that significant transfer occurred between exercises. However, the degree of transfer was not similar between exercises, as the front SQ group increased their hip thrust 3RM by 23.5 kg, whereas the hip thrust group only increased their front SQ 3RM by 5.5 kg. Similar outcomes were reported by Hammond et al. (9) when they compared the transferability between back SQ and hip thrust in 14 resistance-trained males. Specifically, after a 4-week training block, hip thrust and back SQ 1RM significantly increased for both groups. Further statistical analyses suggested that the back SQ group increased their 1RM back SQ by more than the hip thrust group, whereas the opposite was true for the hip thrust 1RM (i.e., the hip thrust group outperformed the back SQ group). Synthesizing these results, hip thrust training transferred to front SQ and back SQ strength, but simply training these movements led to better outcomes (i.e., specificity). Future research can assess whether performing hip thrusts in concert with front/back SQ leads to superior adaptations for strength and power, especially in highly-trained lifters.

The DL and SQ are more traditional exercises used to develop lower-body strength, and potential transfer between them may provide rationale for diversifying exercise selection. A recent study by Nigro et al. (17) assessed transfer between these exercises as they randomly assigned 25 resistance-trained males to 1 of 2 experimental conditions: DL (n = 14) or SQ (n = 11). After 6 weeks of training, both groups significantly increased their SQ 1RM, but the SQ group increased by more than the DL group. Similar results occurred for the DL 1RM, as both groups increased, but the DL group increased by more than the SQ group. These data provide strong evidence for specificity and transferability as both exercises can be used to increase maximal strength for the trained and untrained exercises (17). When applying these studies to practice, it is recommended that SCSs use multiple lower-body exercises concurrently during a periodized training plan and to include specific training phases that emphasize one over the other (6,9,17).

Because of the recent health and economic constraints surrounding the COVID-19 pandemic, SCSs may need to find substitutions for traditional barbell exercises. Thus, the research by Maulit et al. (14) is especially pertinent, as they compared the effect of kettlebell swings to explosive DL (maximal effort with 30% of 1RM) in resistance-trained men (>1 year). After 4 weeks, both groups significantly increased their maximal DL strength and VJH with no differences between them. In their discussion, the authors highlighted that both groups used low intensities and focused performing each repetition with maximal effort and velocity, which explains why both groups significantly increased their VJH and rate of force development. When considering transfer, it is notable that merely 8 sessions of kettlebell swing increased DL 1RM by 8 kg, meaning that SCSs can cycle through both exercises and prescribe training blocks that use kettlebell swings as a primary hip hinge pattern (14).

TRANSFER BETWEEN UNILATERAL AND BILATERAL LIFTS

There is a robust discussion surrounding the utilization of unilateral or bilateral exercises, especially when considering neuromuscular outcomes such as the cross-education effect, bilateral deficit, and bilateral facilitation (8,13). It is often claimed that unilateral exercises are a better option for increasing athletic performance because they place greater stability demands on the lumbopelvic girdle (15) and will transfer better to athletic skills that require cyclical phases of single-leg stance (1). This concept was researched by Speirs et al. (26) when they assessed the transferability between SQ (i.e., bilateral) and rear foot elevated split squat (i.e., unilateral; RESS) in 18 academy rugby players with at least 1 year of RT experience (Figure 2). Results revealed significant transfer between lifts as 1RM for SQ and RESS increased similarly between groups. Moreover, both lifts transferred to sprint/agility performance as both groups similarly improved their 40-m dash and proagility shuttle. Indeed, compared with SQ, the unilateral nature of the RESS seems to be more similar to linear sprinting and change-of-direction tasks, but these data suggest that both were equally effective.

As it pertains to strength, similar results were reported by Appleby et al. (2) when 8 weeks of barbell step ups increased SQ strength, and vice versa, in young rugby players. Both groups improved their 20-m sprint time, but only the SQ group improved their change-of-direction ability, which contradicts the findings of Speirs et al. (26). These disparate outcomes for agility performance can be explained by the muscular actions of each exercise. For example, it is possible that the concentric phases of SQ, RESS, and step ups transferred to faster linear speed by increasing peak ground reaction forces, which are essential for the initial phases of sprint acceleration (1,26). By contrast, change of direction (i.e., proagility shuttle drill) requires quick transitions between deceleration/acceleration and significant eccentric strength (1). Thus, it is likely that exercises with significant eccentric phases (e.g., SQ and RESS) transfer better to change-of-direction tasks than concentrically oriented exercises such as step ups (1,26).

Taken together, the research by Speirs et al. (26) and Appleby et al. (2) suggests that unilateral and bilateral exercises are equally effective at stimulating strength in trained exercises, untrained exercises, and sprint speed. However, when improved change of direction is a desired outcome, it seems that selecting exercises with significant eccentric phases are more important than the bilateral/unilateral orientation of the exercise.

Above all, the selection of unilateral/bilateral does not have to be binary, and SCSs should consider the unique advantages for each style of RT when designing programs. Specifically, the stability and balance demands are greater during unilateral exercise (2), and the lower external loads may be beneficial to allow soft tissue structures to "deload" after blocks of training with heavier external loads (e.g., during preseason and in-season training) (26). By contrast, there will be times during a macrocycle (e.g., during off-season training) where an athlete/client may want to use heavier external loads to improve force production and recruitment of higher threshold motor units, for which a bilateral exercise may be a better choice (1).

TRANSFER BETWEEN SINGLE- AND MULTIPLE-JOINT LIFTS

Personal trainers may consider the unique benefits of including MJ and single-joint (SJ) exercises when designing RT programs for their general population clients. For example, some have argued that MJ exercises are superior because they cause greater metabolic stress, higher muscular activation, and more closely emulate activities of daily living and/or sport-specific movements (5,27). In a different context, SJ exercises have unique advantages because they require less technical demand and allow a lifter to isolate specific muscle groups (5,27). To assess transfer between SJ and MJ exercises, Paoli et al. (18) recruited 36 untrained males and randomly assigned them to SJ or MJ training. At the end of the intervention, both groups significantly increased their 1RM for bench press, back SQ, and knee extension, but greater improvements were observed in the MJ group. These data demonstrate transferability between SJ and MJ exercises as both groups increased their strength in untrained exercises, but MJ exercises were a more efficient option for increasing maximal strength (18).

Similar results were reported by Stein et al. (27) who studied transfer between MJ (leg press [LP]) and SJ (gluteal kick back + knee extension) training in 53 untrained females. Data revealed that both groups significantly increased their LP 6RM, but MJ outperformed the SJ group. For the SJ exercises, both groups significantly increased their 6RM for gluteal kickback and knee extension, but the SJ group improved by more than the MJ group. Compared with Paoli et al. (18), these results demonstrate a higher degree of specificity because those who trained SJ exercises experienced greater increases in SJ strength (27). Methodological differences may explain the disagreement between studies as Stein et al. (27) had their SJ subjects train with higher intensities (6–10 vs. 12–18 RM) and weekly volume (6–12 vs. 4 sets/week) compared with Paoli et al. (18). When extrapolated over the span of 8 weeks, these differences resulted in 54 versus 32 total sets of knee extension for Stein et al. (27) and Paoli et al. (18), respectively.

In general, research demonstrates that SJ and MJ exercises follow patterns of

Figure 2. An example of transferability between unilateral and bilateral lower-body exercises (e.g., rear foot–elevated split squat and back squat) as demonstrated by Speirs et al. (26). The subjects in the rear foot–elevated split squat group increased their back squat 1RM by 10 kg despite not training the back squat during the 5-week mesocycle of training. 1RM = 1 repetition maximum.

Figure 3. An example of transferability between single- and multiple-joint lower-body exercises (e.g., hip extension and knee extension to leg press) as demonstrated by Stein et al. (27). The subjects in the single-joint group increased their leg press 6RM by 10 kg despite training hip extension and knee extension for 8 weeks without training the leg press. RM = repetition maximum.

transferability/specificity, and including them in a RT program should be decided by an individual's time constraints and desired outcomes. For example, de Franca et al. (7) reported that the addition of SJ exercises increased training session duration by ~40% but did not result in superior maximal strength for elbow flexion/extension when compared with MJ training alone. Thus, if a client or athlete is pressed for time, MJ training may deliver similar adaptations in a more time-efficient manner. In a similar fashion, if a client or athlete's primary goal is to increase strength in a MJ exercise (e.g., SQ), SJ and MJ training can help achieve this goal (5), but simply performing MJ exercises may be a more viable option. Considering the same example, supplementing the SQ with a SJ exercise (e.g., knee flexion) may be appropriate to help maintain muscle balance (27), which ultimately demonstrates that MJ and SJ exercises play synergistic roles in a RT program.

MACHINE VS. FREE-WEIGHT EXERCISES

The specificity/transferability of strength can also be discussed in the context of machine-based versus free-weight exercises. Although they can train similar muscle groups (e.g., LP versus SQ), machine-based RT requires much less stability and may allow lifters to isolate muscles better, especially when a cam system is used (25). By contrast, the greater stability requirement of free-weight exercises increases muscular activation and may transfer better to athletic performance (28). In a comparison between the 2, research by Wirth et al. (28) concluded that LP and SQ training stimulated similar increases in 1RM for their respective exercises, but VJH increased only after SQ training. There were 2 primary limitations of this article. First, the transfer of strength across exercises was not measured, and second, the researchers did not assess a hybrid approach of using LP + SQ in the same program (Figure 3).

The limitations of Wirth et al. (28) were addressed by Rossi et al. (22) who randomly assigned untrained males to 10 weeks of SQ, LP, or SQ + LP training. Results indicated that all groups increased their 1RM for SQ, but the SQ training group improved 1RM more than the LP and SQ + LP groups. Conversely, all 3 groups improved their 1RM for LP and VJH with no differences between them. Regarding VJH, the authors highlighted that effect sizes and percent increases were largest in the SQ group, followed by the SQ + LP and LP groups (22). For maximal strength, these studies demonstrate that LP training transfers to SQ strength, but the degree of transfer is greater from SQ training to LP strength. Moreover, SQ training transfers better to VJH performance, which likely stems from similar motor patterns, ground force reactions (e.g., closed chain), muscle activation, and degree of hip extension trained (22,28) (Figure 4).

Personal trainers should also consider the unique benefits of machine-based versus free-weight training as some general population clients may be more concerned about hypertrophy and strength than VJH or athletic performance. For example, a recent study by Schwanbeck et al. (25) compared the effect of machine versus free-weight training in resistance-trained males and females. After 8 weeks of lifting, results revealed that both groups significantly increased their 1RM for smith-machine bench press, smith-

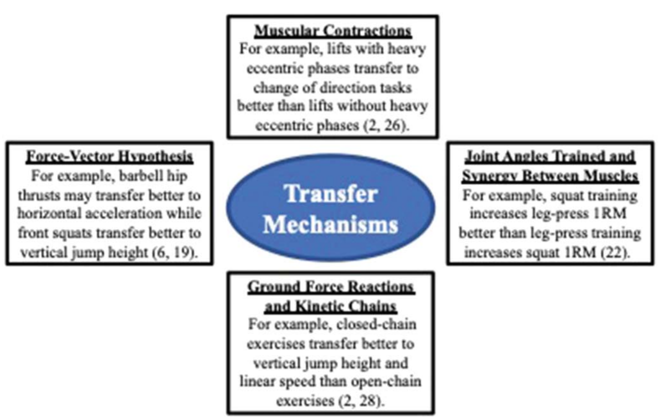

Figure 4: A summary of 4 proposed mechanisms that cause transfer between exercises (e.g., squat to leg press) and between exercises and performance (e.g., front squat and vertical jump height).

machine SQ, free-weight bench press, and free-weight SQ, suggesting transferability between free-weight and machine-based training. Similarly, both training programs elicited significant skeletal muscle hypertrophy, as biceps brachii and vastus lateralis muscle thickness increased for both groups. When maximal strength is the goal, research suggests that machine-based training transfers to free-weight performance (20) and vice versa (22), whereas hypertrophy may occur regardless of modality (25). However, if VJH is your client's or athlete's primary goal, the literature suggests that SQ is better than LP (22,28). Given the intriguing data by Schwanbeck et al. (25), future research should compare the effects of SQ, smith machine SQ, and LP to assess the influence of posture, degree of instability, and ground force reactions on transfer to VJH performance.

CONCLUSIONS

Strength and conditioning research has traditionally focused on the transfer of power and strength from RT to athletic performance (2,19,22,26,28,29). More recently, transfer has been studied in the context of increased strength in untrained exercises (6,9,14,17,18,25,27). Considering bilateral lower-body ground-based exercises, there is evidence of transfer between hip thrust and front SQ (6), hip thrust and back SQ (9), DL and back SQ (17), and kettlebell swing and DL (14). However, specificity predominated in these studies because 1RM increased by more in the trained exercises (6,9,14,17). Pertaining to unilateral and bilateral exercises, research has demonstrated equal transfer of strength between back SQ and RESS (26) and back SQ and step ups (1,2). All 3 of these exercises improved linear sprint speed (1,2,26), but only exercises with a significant eccentric phase transferred to change-of-direction performance (2,26). Personal trainers may also consider transfer between exercises, especially when they write programs for general population clients. For example, there is evidence of transfer between SJ and MJ exercises (5,7,18,27), but MJ training may increase strength in a more time-efficient manner (5). Moreover, recent research has demonstrated that machine-based training transfers to free-weight strength and vice versa (22,25), but free-weight training may transfer better to lower-body power (e.g., VJH) (22,28). Future research should assess the influence of gender, training status, and age on transfer between exercises. Moreover, in light of the COVID-19 pandemic, it would be interesting to assess transfer between simple RT exercises and traditional gym exercises (e.g., body weight isometric lunge vs. barbell split SQ). Above all, exercise selection does not need to be a binary decision. Several variations of lifts should be introduced during a periodized RT program, and exercises can be included/excluded based on the goals of each specific training block.

PRACTICAL APPLICATIONS

When strength acquisition is the primary goal, it is recommended that SCSs use several lower-body exercises concurrently during a periodized training plan and to include specific training phases that emphasize one over the other (6,9,17). In fact, providing a variety of exercises may increase motivation (4) and hypertrophy/strength by virtue of increased training volume (21). Unilateral and bilateral exercises increase strength and sprint speed similarly (1,2,26), but exercises with significant eccentric phases (e.g., SQ and RESS) should be emphasized when agility is a desired outcome (2,26). Considering time of the year and phases of a periodized RT plan, bilateral exercises could be used during off-season and pre-season lifting, whereas unilateral exercises could predominate as the athletes get closer to their competitive season. Indeed, strength transfers between MJ and SJ exercises (5,7,18,27) and both should be included in a training program based on time commitment, preference, and requirements for sport. Personal trainers and SCSs can help athletes increase hypertrophy (22,25) and strength (20,22,25,28) by using free-weight and machine-based RT, and they should consider the unique benefits of both. Specifically, free-weight training should predominate when improvements in lower- and/or upper-body sport-specific power are the goal, but machine-based training should be used if the goal is to isolate/activate a specific muscle to increase muscle size and/or strength.

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