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Transfer of Training: How Specific Should We Be?

1. How is a target task defined?
   A. an exercise used as a means of training
   B. the desired outcome within the sport
   C. the intended movement outcome

2. What is common to the various models of training organization discussed?
   A. All strength training exercises must transfer to a specific sporting movement.
   B. The development of capacities is separate from that of technical abilities.
   C. It is acceptable for training tasks to be part-specific to a sporting movement.

3. Which approach focuses on developing general capacities to benefit the athlete?
   A. traditional
   B. coordinative
   C. mixed-methods

4. What does the intention-action model explain about the brain and central nervous system?
   A. They work backward from the desired outcome to organize the intended movement.
   B. They analyze the pattern after it is initially performed to improve movement.
   C. They organize the intended movement by working forward from the desired outcome.

5. What is the greatest risk of adding excessive load to excessive load to a sporting movement?
   A. The athlete learns to perform the movement more slowly.
   B. It becomes different from the targeted movement task.
   C. Strength is increased more than movement speed.

6. Which is a potential mechanism by which traditional overload exercises may enhance performance?
    A. reduced antagonist activation
    B. diversification of sensorimotor solutions
    C. increased motor unit recruitment

7. What does Bosch’s model suggest as a first step to ensuring specificity?
    A. similarity of muscle activity type
    B. overload through increased load
    C. dynamics of the intended effort

8. What is meant by the term “muscle slack”?
    A. the amount of muscle mass involved in a movement task
    B. delay between muscular activity and tendinous tissue recoil
    C. reduced in muscle tension prior to force production

9. What is the effect of increased muscular strength on the rate of force development (RFD)?
    A. It increases RFD.
    B. It decreases RFD.
    C. Research is equivocal.

10. What does research suggest about the effect of an athlete’s status on transfer?
    A. Transfer is achieved to a greater degree by elite athletes.
    B. Transfer is achieved to a greater degree by subelite athletes.
    C. Transfer is the same regardless of the athlete’s status.

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Transfer of Training: How Specific Should We Be?

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ABSTRACT

A SPECTRUM OF APPROACHES EXISTS AMONG STRENGTH COACHES AS TO THE DEGREE OF SPECIFICITY REQUIRED TO OPTIMIZE TRAINING TRANSFER TO TARGETED ATHLETIC PERFORMANCE. THE "PROBLEM" WITH SPECIFICITY IS THAT IT IS IN CONFLICT WITH OVERLOAD. SOME GIVING PRECEDENCE TO SPECIFICITY FIND A SOLUTION IN APPLYING OVERLOAD THROUGH VARIATION, WHEREAS OTHERS SEEK TO TRADITIONALLY OVERLOAD 1 OR 2 ELEMENTS OF THE SPORTING MOVEMENT. ADVOCATES OF GENERAL TRAINING MORE READILY SACRIFICE SPECIFICITY FOR THE DEVELOPMENT OF CAPACITIES. IN APPLYING THESE CONTRASTING APPROACHES TO THE HYPOTHETICAL TARGET TASK OF ACCELERATIVE SPRINTING, THIS REVIEW COMBINES EVIDENCE- AND LOGIC-LED ARGUMENTS TO EVALUATE THE EFFICACY OF EACH. AS SUCH, A SUMMARY OF LITERATURE IS PRESENTED. IN MOST CONTEXTS, A MIXED-METHODS APPROACH REMAINS RECOMMENDED AS DEGREE OF TRANSFER TO TARGETED ATHLETIC PERFORMANCE APPEARS AS DEPENDENT ON ATHLETE STATUS AS IT IS ON THE SPECIFICITY OF THE TRAINING TASK.

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INTRODUCTION

In strength and conditioning (S&C), the concept of training transfer is a highly debated topic. Training transfer refers to the degree of crossover from a training means to the desired outcome or task (27), for example, the extent to which a power clean impacts 5-m sprint performance. Transfer ultimately determines the worth of training programs and their exercises in the context of improving athletic performance (27). Although training programs are likely to be more general in nature during the early stages of training (10,25,27,31,37,54), as athlete preparation approaches competition time, transference to the target task (sporting movement) becomes a priority, and therefore, training tasks commonly become increasingly similar (11,55).

Various models of organizing training into an effective performance outcome have been proposed within the literature over the past 3 decades. Bondarchuk (11) developed a system of exercise classification, where based on their characteristics, exercises fell into 1 of 4 categories: general preparatory exercises (GPEs), specific preparatory exercises (SPEs), specialized developmental exercises (SDEs), and finally, competitive exercise (CE). Their characteristics were determined by Siff and Verkhoshansky's (45) 5 laws of dynamic correspondence; a criterion proposed to determine an exercise or training program's ability to positively affect the athletes' sporting performance. These were (a) amplitude and direction of movement, (b) accentuated region of force production, (c) dynamics of the effort, (d) rate and time of maximal force production, and (e) regime of muscular work. Within the system, CE would be the target task itself or very minor variations, and SDE would be akin to the traditional notion of the "sports-specific" exercise–mechanically overloading 1 or 2 aspects of the target task and similarity at recruitment level (local specificity). SPE would be chosen for its local specificity too, but the movements may not necessarily resemble even part of the target task, while GPE disregard the specificity principle all together.

Bosch (12) recently added a further layer of rigor to these laws with a model heavily underpinned by motor learning principles. His 3-layer model of specificity proposes that, for a target task to transfer to a training task, the 2 movement patterns must have similarity of (a) intramuscular and intermuscular coordination, similar excursion of the joints (outer movement resemblance) and associated energy production, (b) sensory input about both the environment and their own body (proprioception) and, (c) similarity of intention. The first layer will be familiar to most exercise scientists, whereas the final layers may not. These will be explained further in the subsequent section that will use ecological dynamics to connect motor-learning theory to exercise science. To avoid confusion around

KEY WORDS:
training transfer; acceleration; specificity

terms given that the scope of the article connects these 2 fields, a table of nomenclature is included (Table 1) providing operational definitions strictly for the purpose of this article (it is not the authors' intention to bring new definitions to either field).

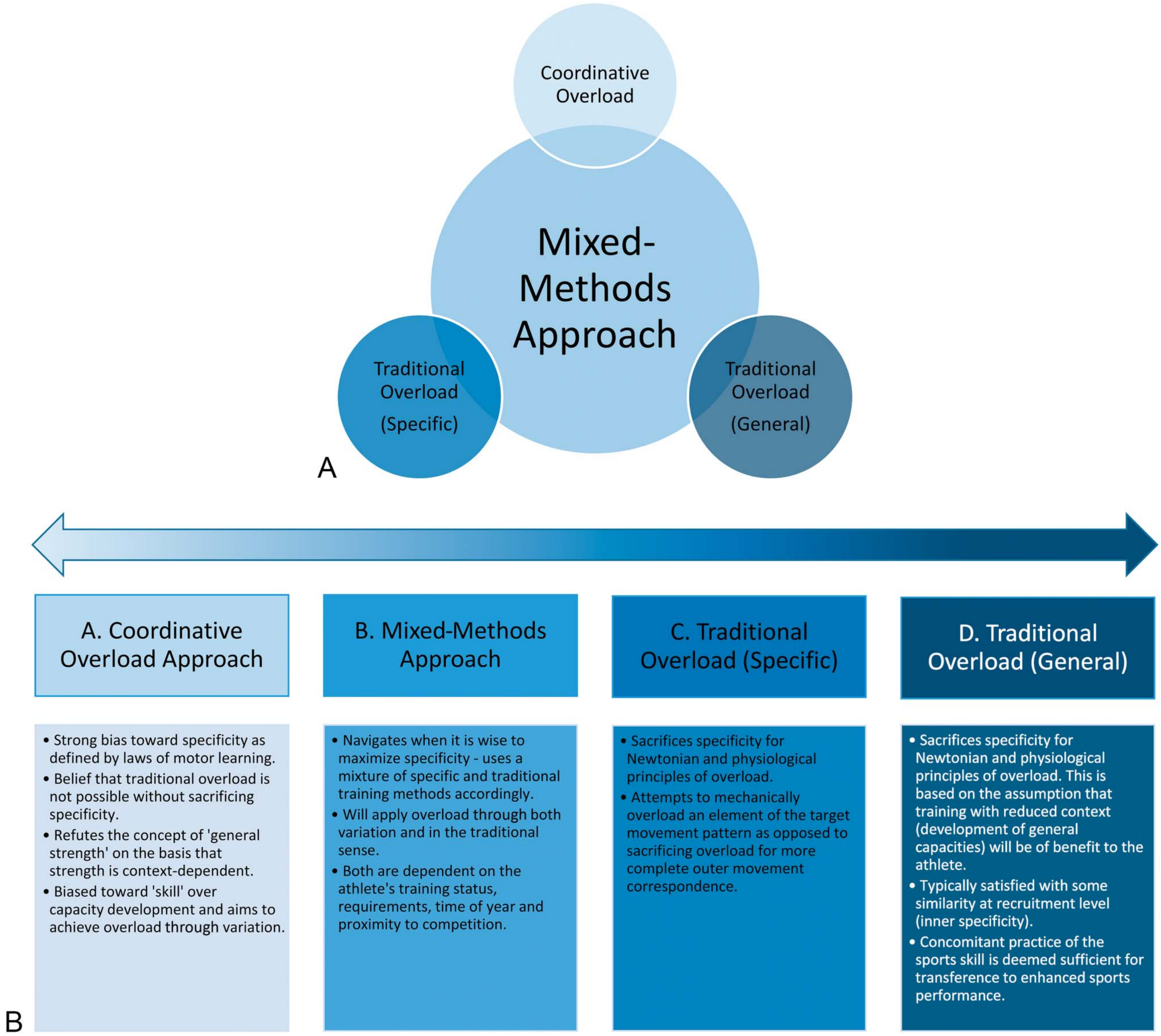
A commonality between the aforementioned models of transfer proposed by Siff and Verkhoshansky's (45), Bondarchuk (11), and Bosch (12) is the agreement that for most target tasks, it is not feasible to design a training task that will meet all their proposed criteria for specificity. This means it is generally acceptable for training tasks to only be part-specific, or for transfer to be sought in only 1 or 2 aspects of the target task movement.

However, in accordance with the rules of his 3-layer model, Bosch (12) contests that "general motor abilities" or capacities such as strength cannot exist based on the fact that it is inextricably linked with skill and coordination and is therefore entirely dependent on the context in which the movement is performed. This is somewhat contrary to a recent review by Issurin (27) who suggests that the development of capacities should be considered separately from the development of technical abilities (skills). This viewpoint was formed based on the school of thought that the transfer of skills is more restricted than the transfer of capacities (61). In other words, skill development requires practice of the specific task to be effective, whereas strength (e.g.) can be developed in a more generalized manner and still have the potential to carry a transference effect.

Table 1
Table of nomenclature

Terminology	Operational Definition
Transfer	The degree of crossover from a training means to a desired outcome or "target task."
Specificity	A general training principle that describes how a training stimulus has a specific effect due to a host of underlying mechanisms.
Training task	Any exercise, drill, or activity used as a training means.
Target task	The desired outcome within the sport or athletic performance that the training task aims to impact on.
"Global specificity" synonymous with "outer movement correspondence"	Dynamics, velocity, amplitude, and direction of a movement.
Local specificity	Similarity at recruitment level: Muscle activity type, type of force production and musculo-tendinous unit behavior (passive versus active), rate of force production, intramuscular and intermuscular coordination.
Capacities	Ability to express a given quality—force, range of motion, and endurance.
Skills	Technical abilities—an ability to control their body accurately, efficiently, and in a timely manner (16).
Structure	Typically in reference to cross-sectional area or architecture of a muscle/muscle tendon unit.
Noise	Error or corrective mechanisms in the motor program.
Intention	In relation to the intention-action model. The desired outcome of a movement resulting in its organizational strategy.
Intent	In relation to training with intensity, for example, to move the bar as quickly as possible in weightlifting.
Neural drive	The neural activation signal received by a muscle from the pool of innervating motor neurons. Has been calculated as a percentage of octet force achieved by voluntary force at a given time interval (i.e., 50 ms) (49).
Athlete status	The level the athlete has attained in their respective sport together with their physical training history.
Coordinative overload/overload through variation	Altering a training task in such a way that it causes the athlete to exhibit increased movement variability and subsequently provokes an adaptive level of stress.

Broadly speaking, the opposing viewpoints of Bosch (12) and Issurin (27) largely explain why differences in approaches exist. Opinion is divided between those insisting that training tasks need to be highly specific to the target task, and those who believe in the concepts of generalization; that capacities acquired in training can be applied in the sports skill. Explicitly, the former values specificity as defined by laws of motor learning and seek coordinative overload, whereas the latter more willingly disregards specificity for traditional Newtonian and physiological principles of overload. Accordingly, we will refer to these as the coordinative overload approach and the traditional overload approach, respectively. Although coordinative overload tasks are inherently specific, another general-specific spectrum exists within the traditional overload approach. Although, for some, their bias toward traditional overload does result in a more general training outlook, many retain a partly specific approach. This is typically achieved by mechanically overloading just 1 or 2 elements of the target task, accepting that the application of traditional overload to a global movement pattern is often unrealistic. Advocates of a more general traditional overload approach are usually not concerned with outer movement correspondence as long as there is some similarity at recruitment level (local specificity). For clarity, a schematic of these viewpoints has been created to aid the reader through this article (Figures 1A and 1B). Although there is the option that



A. Coordinative Overload Approach	B. Mixed-Methods Approach	C. Traditional Overload (Specific)	D. Traditional Overload (General)
• Strong bias toward specificity as defined by laws of motor learning. • Belief that traditional overload is not possible without sacrificing specificity. • Refutes the concept of 'general strength' on the basis that strength is context-dependent. • Biased toward 'skill' over capacity development and aims to achieve overload through variation.	• Navigates when it is wise to maximize specificity - uses a mixture of specific and traditional training methods accordingly. • Will apply overload through both variation and in the traditional sense. • Both are dependent on the athlete's training status, requirements, time of year and proximity to competition.	• Sacrifices specificity for Newtonian and physiological principles of overload. • Attempts to mechanically overload an element of the target movement pattern as opposed to sacrificing overload for more complete outer movement correspondence.	• Sacrifices specificity for Newtonian and physiological principles of overload. This is based on the assumption that training with reduced context (development of general capacities) will be of benefit to the athlete. • Typically satisfied with some similarity at recruitment level (inner specificity). • Concomitant practice of the sports skill is deemed sufficient for transference to enhanced sports performance.

Figure 1. (A) Approaches to training transfer. (B) Defining approaches to training transfer.

elements of both should be included in a more holistic approach to athlete preparation (mixed-methods approach), given the contrasting opinions surrounding the need for a more specific approach to athlete training programs, this article is warranted.

As such, the following sections of this narrative review endeavor to describe concepts and research that engage a coordinative overload approach versus a traditional overload approach, as well as discussing when it may be wise for those adopting the latter to maximize specificity, and when a general approach may be more beneficial. To provide context and exemplify the discussion for the reader, the authors will draw on a recurring example target task throughout. In light of its applicability and importance to a large amount of field-based sports, we will use the example of accelerative sprint running. This has been selected over maximal velocity sprinting because field-based sports often do not afford its athletes the time or conditions to reach maximal velocity (60).

THE COORDINATIVE OVERLOAD APPROACH

Theoretically, the coordinative overload approach is underpinned by the notion that human movement control is a dynamical (nonlinear) system that behaves in a self-organizing manner (29,34). This emergent behavior (not a feedback mechanism) also inherently carries a high degree of noise, and therefore, rigid motor programs probably do not exist, but rather various flexible motor programs interact with sensory information to result in a movement outcome (12). Accordingly, imposing a "coordinative overload" is in theory a way of creating ever-new or more flexible sensorimotor patterns, so that the athlete can continue to learn and diversify their movement solutions to a given task. Their ability to cope with the inherent variability or noise associated with the task improves, and they are better equipped to find stability in positions that matter regardless. In other words, they become more skillful at it.

Relating back to training practice, the coordinative overload approach centers around a redefining of the term "overload" beyond Newtonian or physiological terms. To elaborate, Bosch (12) explains how as well as the routine addition of more kilograms to a barbell; overload can also be sought through imposing variation. In other words, imposing deviations of the target task which is familiar to the athlete. For example, high-speed running is a skill that the athlete is likely to have refined over and over, and therefore, by imposing a novel intermuscular coordinative pattern (i.e., creating instability with uneven surfaces or a gradient), this causes the athlete to exhibit more variability than usual, and adaptation must occur for the organism to process this (12). To satisfy Bosch's (12) three-layer model of specificity, it is important that these deviations are small, so that the pattern of recruitment remains similar to that of the target task. Bosch (12) provides further examples of coordinative overload tasks for high-speed running. These include a single-leg clean to step (Figure 2) and step up's performed in series (Figure 3), which he deems similar to the toe off phase of sprinting, where the athlete must resist rotations around the longitudinal axis (12).

To exemplify the application of a coordinative overload approach, Table 2 applies the concept to Bondarchuk's (11) exercise categorization, demonstrating exercise selection for our hypothetical target task. Although the readership will be more familiar with a traditional overload approach, the table also shows a traditional assignment of exercises for each category for purpose of comparison. Having now defined the coordinative overload approach, the remainder of this section will outline in more detail the key considerations when designing coordinative overload tasks and review the existing research supporting such an approach.

Table 2 demonstrates how respective approaches are likely to influence training task selection within each of Bondarchuk's (11) proposed categories. Given that it becomes increasingly difficult to apply traditional overload to highly specific training tasks without diminishing correspondence, coaches with a highly specific training philosophy apply overload through variation as a solution to this. On the other hand, highly specific traditional overload approaches are satisfied with mechanically overloading an element of the target task movement (e.g., med ball dive throw and resisted hip flexion), and more general traditional overload approaches will typically be satisfied with local specificity (e.g., explosive hip thrusts). During general preparation, a coach with a bias toward traditional overload may use tools such as deadlifts or hip thrusts to evoke structural change or to develop general capacities, whereas those with a strong bias toward a coordinative overload approach may neglect GPE altogether. Instead, they may choose to apply overload through variation to SPE from the outset.

SIMILARITY OF INTENTION

As discussed, according to Bosch (12) similarity of intention is the core factor determining transfer between 2 movement patterns. The intention-action model, which has been discussed in the literature (12,62), explains the notion that the brain and central nervous system (CNS) work backward from the desired outcome to organize the movement based on the intention. By way of example, in accelerative sprinting, the over-riding intention is to project the center of mass (CoM) horizontally (58), and therefore, proponents of an ecological dynamics approach to skill acquisition would contend that the athlete will self-organize their movement to best deliver this intention (22). Newell's (34) model of constraints is underpinned by ecological dynamics, and in that, it suggests that constraints shape (self-organize) movement outcomes. Specifically, this self-organization is proposed to result from an interaction of subsystems between the task, the environment, and the

Figure 2. (A–D) Single-leg clean to step (top left = start position, top right = hang position, bottom left = pull position, bottom right = catch position).

performer. According to Newell, technique emerges from the constraints imposed on the performer. For instance, a rugby athlete's accelerative sprinting technique is believed to differ to that of a track sprinter as a result of the associated cognitive perceptual demands (requiring them to maintain a head-up posture to scan and react to stimuli). This is an example of how sensory input can influence the performer technique; the intention is

Figure 3. (A–E) Switch step ups performed in series with added stability challenge (top left = start position, top right = step 1, middle left = step 2, middle right = step 3, bottom = finish position).

Table 2
Influence of viewpoint bias on training task selection for acceleration ability

Training Task Category	**Category Definition**	**Example Task Selection**			**Key**
		Coordinative overload bias	**Traditional overload bias**		
Bondarchuk's Model (12)	A combination of Bondarchuk and Siff (12), and Verhoshansky's (58) models		*Specific*	*General*	
Skill Overload Exercise	Tasks which pursue overload via variation and have a large impact on target task skill (technique)	Short hill sprint, no arm acceleration, uneven surface sprinting	Light resisted sprint	N/A	Skill development
Special developmental exercise	Tasks which have a large degree of kinematic similarity to the target task, and satisfy all the rules of dynamic correspondence	Stair sprints with stability challenge (e.g., aqua-bag overhead)	Sled bounds, medicine ball dive throws	N/A	↕
Specific preparatory exercise	Tasks which have little kinematic similarity to the target task, but satisfy some of the rules of dynamic correspondence	Single-leg clean to step (Figure 2) or switch step ups performed in series with stability challenge (Figure 3)	Heavy sled towing, resisted hip flexion	Single leg hip or hang snatch or clean, explosive hip thrusts, step ups	
General preparatory exercise	Tasks designed to develop capacities but have little (acute) impact on target task skill (technique)	N/A	Clean, squat jump, deadlift, Romanian deadlift, split squat	Clean, squat jump, deadlift, Romanian deadlift, split squat	Capacity development

still to project their CoM, yet now they also have to navigate opponents to ensure they avoid being tackled. Similarly, an alteration to the task may impose another boundary that in turn shapes a new organizational strategy. For example, the addition of resistance to accelerative sprinting has been found to increase ground contact times (58). It is believed that when technique is reshaped in such a way, this is a self-organization in the interest of achieving the over-riding intention despite the changes to the task (the prolonging ground contact affords the athlete more time to project the extra mass horizontally). As long as the alteration to the task is not so drastic that the reorganizational strategy adopted by the CNS is not vastly different to the target task, then transfer should be possible (12). This is why, as discussed, coordinative overload tasks are inherently subtle variations of the target task (and therefore highly specific) to avoid too much diversion and diminished transfer potential. It also highlights the danger of selecting or designing training tasks rashly on intuition based on visual resemblance alone, such as adding excessive load to a sporting movement such that it becomes too dissimilar to the target task. Cleather (17) coined this potential pitfall as the "specificity trap."

TRADITIONAL OVERLOAD APPROACH

The principle concept engaging the traditional overload approach is that enhancing capacities (such as those listed in Table 3) through training is an effective way to enhance performance in an athletic target task such as acceleration. Although the previous section began with a defining of the coordinative overload approach, the authors assume the traditional overload approach will be familiar to the readership. Therefore, this section will proceed to discussing the efficacy of a specific or general approach, drawing on the existing body of evidence within the literature. First, it will consider the evidence supporting the concept of strength specificity. Throughout this

Table 3
Mechanisms underpinning coordinative and traditional overload

Potential mechanisms by which 'coordinative overload' exercises may enhance performance (skills)	Potential mechanisms by which 'traditional overload' exercises may enhance performance (capacities)
Inter-muscular coordination (reduced antagonistic activation and increased synergistic activation in highly similar patterns of recruitment to the target task).	Peripheral: increased cross-sectional area, fascicle length, stiffness (tendon and passive elements), collagen content of extracellular matrix, changes in pennation angle, shift in expression of myosin heavy chain isoforms.
Intra-muscular coordination (diversification of sensorimotor solutions)	Neural: increased neural drive and activation, increased motor unit recruitment, increased rate coding.

section, particular attention will be paid to subject characteristics (training status) to observe how this may affect transfer, with a view to exploring whether any general recommendations can be made as to when training should become more specific.

SPECIFIC STRENGTH TRANSFER

Although a coach may not use variation as a means of imposing overload, their exercise and program design may still reflect strength specificity principles. Coaches who use traditional roads to overload yet adopt a highly specific approach typically attempt to mechanically overload an element of the target task, as opposed to sacrificing overload for outer movement correspondence (global specificity) as in the coordinative overload approach. At the very least, local specificity at recruitment level is deemed paramount, something that is largely dictated by similarity of intramuscular and intermuscular coordination, as well as velocity and task time constraints.

Intramuscular coordination. The phrase "specificity is on the inside" describes how the local interactions, mechanisms, and behavior of the musculotendinous unit are potentially more important for transfer than outer movement resemblance. Intramuscular coordination describes the behavior (particularly, the type of activity–isometric, eccentric, or concentric) within a single muscle. Bosch's model (12) suggests that similarity of muscle activity type is one of the first steps in ensuring specificity (Bosch's model also demands some similarity of outer movement resemblance and therefore similarity of intention, hence why training tasks associated with his model more often than not apply overload through variation as seen in Figure 2A–2D), and there is a large body of work that has highlighted its significance in the transfer of strength. Baker et al. (5) set out to challenge the concept of "general strength" in his correlational study design, investigating the relationship between isometric and dynamic measures of strength. There was a preintervention relationship between 1 repetition maximum back squat and isometric leg extension ($r = 0.57$), but it was not significant. After training, the improvements seen in both were again unrelated ($r = 0.16$) suggesting different mechanisms of adaptations led to improvements in dynamic and isometric strength. The study also examined speed-strength measures through isoinertial (vertical jump height) and force-time variables during an isometric leg extension (time taken to reach 400 N and impulse). The intervention enhanced vertical jump height (8.3%) but neither isometric force-time variable improved. This is supportive of the notion that strength is not a general capacity and needs to be specific to the target task. More specifically, this research supports how the training task must share the same muscle activity as the target task.

Further to this, Van Hooren et al. (53) found that resistance training had a better transfer to rapid force development in movements with a countermovement versus those without, for untrained or recreationally trained athletes (67% of the measures improved in the countermovement jump [CMJ]; 25% for the squat jump [SJ]). This systematic review suggests that the degree of a countermovement in the target task is probably an important consideration. To contextualize this within our theme of acceleration, this would mean in practice a CMJ would carry less transfer than a SJ to early accelerative sprinting. Theoretically, it has been proposed that a countermovement strategy is a method of taking up "muscle slack." This has been defined as the delay between muscular activity and the recoil of tendinous tissue (53). Accordingly, a large countermovement would allow greater time for the accumulation of neural drive in comparison to a movement with no or little countermovement, so one could appreciate why a CMJ (large countermovement) would carry little transfer to early acceleration (where little countermovement is used). This further supports the importance of intramuscular similarity for transfer.

Intermuscular coordination. Although intramuscular coordination describes the behavior within a single muscle, intermuscular coordination describes the cooperation between different muscles to result in a global movement outcome, for example, the cooperation of the gluteus maximus, hamstrings, and adductor magnus to produce hip extension (12). Dalen et al. (22) demonstrated how altering the intermuscular coordination of a task has the potential to diminish transfer. In his study, one group performed 3 weeks of unloaded SJ training without a plantarflexion (jump initiated from the heel on a box with the medial metatarsus to the toe off the edge of the board in the air) together with separate plantarflexion training. The second group performed unloaded SJs incorporating plantarflexion as usual. The first group resulted in a large increase in time to peak force in the SJ, whereas the second group showed only a trivial increase in time to peak force. This highlights how transfer is also dependent on the similarity of intermuscular coordination between the target and training task.

Furthermore, in their simulation study, Bobbert and Van Soest (9) showed that changes in intermuscular coordination were required to transfer increases in leg strength into higher vertical jumps. This is a plausible explanation for the frequently observed phenomenon that improvements in force production (capacity) often do not result in immediate improvements in athletic performance. Bobbert and Van Soest's (9) findings suggest that this realization is delayed until the relevant intermuscular patterns are sufficiently rehearsed with their newfound strength qualities. This is supportive of the overarching concept that engages a specific approach–that developing a capacity in an unrelated skill (movement) may not transfer readily to a target task.

Velocity. A key barrier when trying to replicate the sporting movement demands within a training task is the velocity of the movement itself. A traditional school of thought is that it is the intent (rather than the resulting movement velocity) to move an implement (or oneself) quickly that is the important factor in transferring strength gains to fast actions such as sprinting (18,44). However, increases in early-phase neural drive are only associated with short duration, high force contractions (6,49,51), so this somewhat nullifies the concept that heavy strength training will transfer to sports movements where the force-time interval may be as little as 10–50 ms and no external resistance needs to be overcome (8,23,30). Indeed, Van Hooren et al. (53) conducted a systematic review and found that, of 12 studies with 271 participants, only 38 and 43% of rapid force development measures (various) improved in unloaded movements (CMJ and SJ) after heavy strength training (sustained maximal voluntary contraction) in untrained and well-trained individuals, respectively. Consequently, the laws of local specificity seem to suggest that training tasks with explosive, short duration contractions are recommended over heavy strength training in well-trained individuals, should acceleration development be the primary goal.

However, it seems that local specificity alone does not fully satisfy the laws of velocity specificity. Van Hooren et al. (53) uphold that it is important to specifically mimic the velocity of the sport movement to retain similarity of coordination and in turn optimize transfers in rapid force development qualities. This is in keeping with previous literature that suggests both the intermuscular coordination associated with the movement velocity and aforementioned neural factors (early-phase neural drive) contribute to adaptations that make strength velocity-specific (8,51). Taking our hypothetical target task, in theory, this means a locally specific training task such as a single-leg hip snatch or a more globally specific; high movement correspondence task such as resisted sprints would carry the potential to transfer to acceleration ability, but through different mechanisms. The former has the potential to transfer through increased neural drive, whereas the latter (which could be considered overload through variation) is more likely to achieve transfer as a result of changes in intermuscular coordination (2,6,32,49,51).

GENERAL STRENGTH TRANSFER

General strength training is typically associated with performing an array of traditional barbell and/or dumbbell exercises (cleans, deadlifts, squats, split squats, lunges, pushes, pulls, and carries). Developing muscular strength through such training is believed to have a significant impact on an athlete's force-time characteristics (46). Given that many movement skills are generic to many sports (i.e., jumping, sprinting, change of direction, etc.), and share the commonality of being underpinned by an ability to express force, general strength training is often deemed sufficient to support transfer. Acceleration, for example, notwithstanding its skill components, is essentially a measure of an athlete's ability to generate net impulse. This subsection will now review the body of research supporting a general approach and specifically consider the efficacy of general strength training for improving accelerative sprint performance. Drawing on the comprehensive review conducted by Suchomel et al. (46), the section will begin by examining the cross-sectional evidence, before focusing on intervention studies that have observed causal effect between general strength training and accelerative sprint performance.

Cross-sectional evidence. An array of cross-sectional evidence exists relating sprint performance with both dynamic and isometric maximum strength (13,18,30,32,33,36,38,47,48,50,57,59). For some, this maintains a case for general strength training; however, it is important to recognize that when this case is made through correlations, this does not necessarily mean causation. The findings from Baker et al. (5) (discussed earlier) led them to question the worth in using isometric strength assessment to assess the dynamic strength capabilities of athletic populations. However, more recently, correlations have been found between isometric maximum voluntary contraction and dynamic performance measures such as agility ($r = -0.52$) and speed ($r = -0.54$) (7,23,56). This suggests that, notwithstanding its inability to reflect dynamic strength performance in this study, isometric force-time variables remain a potentially relevant predictor of athletic performance. In addition, several studies have indicated that improvements in strength do transfer to improvements in rate of force development (RFD) (1,3,24,52), which, in theory, should translate to many generic athletic motor skills, including acceleration (50). This is supported by more cross-sectional research, as summarized in a recent review by Suchomel et al. (46). In this article, 59 studies are reported with 75% indicating a large positive relationship ($r > 0.5$) between maximal strength and RFD.

Effect of athlete status on transfer (long-term trials). Although assessing the relationships between acceleration performance and specific strength qualities is helpful, a better test of transfer is to observe the effect of a given intervention on acceleration ability. Furthermore, a consistent message in the literature is that transfer is achieved much more readily in subelite athletes or those with lower training histories (43,46,53). With this in mind, large positive correlations would be expected between maximal strength or RFD and sprinting performance in untrained individuals, but perhaps not always among truly well-trained. Therefore, a major limitation of the research presented is that many of the subjects would not be considered to be of an elite level or have extensive strength training backgrounds and therefore should be interpreted with caution.

This may explain the findings of Askling et al. (4) who found the use of flywheel (eccentric) leg curls to transfer to improved sprint times in premier league soccer players. The flywheel leg curl performed in the study was open chain and performed on a machine, therefore disregarding numerous specificity principles. In this case, although the athletes were performing at an elite level in their respective sport, it would be unwise to assume a considerable strength training history. Indeed, hamstring injury is on the rise in European soccer, and this has been attributed to poor adherence to well-evidenced hamstring strength protocols (35). Hence, in this case, the athletes' status may have supported transfer despite lack of specificity in the training task. There are other studies that have shown improvements in strength to coincide with improvements in acceleration (15,19,39,40,43), but again, most subjects in these studies were junior soccer players who inherently would have less than substantial strength training backgrounds.

As discussed, even when well-trained subjects have been used (strength training history of >5 years), as in the systematic review by Van Hooren et al. (53), the degree of transfer from heavy strength training to rapid force development has remained variable. Notwithstanding, the fact that 38–43% of subjects (12 studies with 271 subjects) did in fact elicit a degree of transfer would probably be enough for many coaches to retain general strength training within the overall training paradigm. Similarly, in a large meta-analysis and systematic review (171 studies), increases in lower-body strength (back squat) did improve mean sprint performance by 3.11% (43), again a degree of improvement that many coaches would value hugely.

Within the same meta-analysis, the improvement in mean sprint performance was reduced to 2.34% if the analyses were limited to international athletes (43). This underlines how magnitude of improvement is affected by the level of the athlete and their training history (43). However, Hopkins (26) recommends that coaches should invest time in means that would enhance performance by as little as 0.3–1.5% in elite athletes. Subsequently, the findings of Seitz et al. (43) suggest that general strength training can still offer benefits to the elite-level athlete. Moreover, Comfort et al. (18) looked at the association between maximal lower-body strength and sprint performance in professional rugby league players during a preseason strength training intervention. Relative squat strength (kilogram per body mass) started at 1.78 ± 0.27 and improved to 2.05 ± 0.21. Furthermore, 20-m sprint times improved from 3.03 ± 0.09 to 2.85 ± 0.11 seconds at the end of preseason. This study design was pragmatic, in that the players were subjected to their usual strength and power preseason mesocycle. However, this made it challenging to determine whether these improvements came as a direct consequence of the back squats. Regardless, this is a notable finding nonetheless due to the group's pre-existing strength and elite level.

Of the studies that have examined, the mechanisms of transfer from general strength training, structural adaptations, neural adaptations (neural drive), and muscle fiber-type transformation were the most common. It is likely that these mechanisms are also responsible for the large amount of cross-sectional evidence for general strength transfer. This does not contest the findings of Baker et al. (5) whereby a generality of strength does not exist, rather it highlights how transfer is as dependent on the athlete's status and existing physical characteristics as it is on the training means. This makes it difficult to offer generalized recommendations around a juncture where exercise selection should become more specific in the interest of training transfer.

MIXED-METHODS APPROACH

The body of the research discussed so forth aids our understanding of the mechanisms underpinning transfer. Notably, how adaptations from strength training are specific, but also how strength training with reduced context can still offer benefit to the athlete. From this, we can deduce that exercise specificity does not solely dictate transfer of training. Accordingly, this section will outline the advantages of a multifaceted, mixed-methods approach.

THE ISSUE WITH DISTINGUISHING APPROACHES

As recently highlighted by Cleather (16), the issue with Issurin's (27) differentiation between skills and capacities is that most expressions of movement stem from an interaction of both. For instance, in accelerative sprinting, the athlete must have the capacity to express the requisite force but also have the skill to direct this force in the most efficient manner. Also, this clearly makes it difficult to differentiate between coordinative overload and traditional overload tasks. By way of example, resisted or weighted-vest sprinting could be considered overload through variation (the variant being addition of a small amount of resistance that retains similarity of coordination) or traditional overload (given that it is still involves the addition of weight/resistance). Indeed, "combining technique with strength qualities" is Bondarchuk's (11) classic definition of a skill-overload exercise, which aligns to the notion of skills and capacities being inextricably linked in many sporting movements (16). The point here is that the adaptations from coordinative overload or specific training tasks are more (but not entirely) skill-based and the adaptations from traditional overload or general training tasks are more (but not entirely) capacity-based. Perhaps, in reality, this means most coaches adopt a mixed-methods approach. Notwithstanding, a spectrum still exists as to the extent to which coaches place emphasis on specificity to transfer to (or favorably modify) target task skill. The subsequent section will discuss how a combination of specific and general training may be the optimal way of achieving this, and thus, why a mixed-methods approach is recommended.

MIXED-METHODS TRANSFER

An insight of elite coaches described by Burnie et al. (14) was that using nonspecific strength training or developing "gym strength" in conjunction with "resisted sport movement training" (e.g., resisted sprinting with sleds, overgeared cycling efforts, etc.) increased the chances of transfer. This makes sense in light of Bobbert and Van Soest (9) and Dalen's (21) findings that the relevant intermuscular coordination patterns must be rehearsed to transfer leg strength. Moreover, this is also supported by Newell's (34) model of constraints, which suggests that altering organismic constraints (i.e., enhancing capacities such as strength) will eventually lead to changes in coordination patterns in a given task such as acceleration. In other words, as discussed earlier, it is likely that the "resisted sport movement training" provided the opportunity for the athlete to learn to apply the new "gym strength" gains in the relevant intermuscular pattern of recruitment, highlighting the advantage of a mixed-methods approach.

Tracking athlete status. Exploring the mechanisms underpinning general strength transfer highlighted the importance of athlete status. Therefore, tracking this in the interests of balancing specific and general training is important. One method of doing this which is growing in popularity within sports involving jumping and sprinting is force-velocity profiling (FVP). FVP can inform whether the athlete needs to get stronger at low velocities or stronger at high velocities to move closer toward a theoretical, optimal mechanical profile (41). The theoretical background of the mechanical profile is underpinned by an inverse linear relationship between force and velocity, where the slope of this linear relationship during lower-limb ballistic tasks denotes an athlete's mechanical profile (40,42). An optimal mechanical profile essentially refers to the best balance between force and velocity characteristics. For a more in-depth theoretical background and validation of these methods, the reader is advised to consult the work of Samozino et al. (41,42). FVP nicely exemplifies how sometimes sacrificing specificity for overload can lead to enhanced performance in a target task. For example, should the athlete require more strength at low velocities, temporarily sacrificing velocity specificity for overload may be of greater benefit to the athlete in the long term. Indeed, this was demonstrated in a longitudinal control study, which showed that force-deficient athletes improved their vertical jump through a force-orientated training program (back squats, leg presses, deadlifts, clean pulls, and loaded jumps with 70–80% body mass) to a greater extent than those who had a balanced training program (equal focus on all areas of the force-velocity spectrum) (28).

Furthermore, back to the context of acceleration, a recent study by Cross et al. (20) compared 2 resisted sprinting training protocols, which used loads decreasing maximal sprinting velocity by 50 and 10%, respectively. Although their findings were that both protocols had minor effects on sprint performance (average −1.4 to −2.3%), the results from both groups varied widely between individuals, which the authors attributed to their preintervention force-velocity characteristics. Moreover, in another study, very heavy sled sprints were found to be more effective at improving short sprint performance than lighter or unloaded sleds (34). This suggests that a more informed approach based on FVP could have further optimized transfer for each of the individuals within the study. It also demonstrates how sometimes a degree of diversion away from the specific movement demands of the target task is sometimes necessary to open up alternative avenues for overload, optimizing transfer for the individual.

CONCLUSION

Specificity and overload are conflicting principles of training. General strength training is not guaranteed to transfer to improved accelerative sprint performance (especially in elite athletes) because of critical differences in both outer movement correspondence and local specificity. Coordinative overload tasks sacrifice less specificity because they have greater potential to produce the relevant coordination patterns, something that becomes increasingly difficult if applying traditional overload to specific training tasks. Nonetheless, adhering to strength specificity somewhere in the training paradigm seems critical if the coach is seeking training transfer, even if the similarity lies solely at recruitment level.

Transfer certainly seems largely affected by athlete status, in that general strength training may have less to offer an elite-level athlete who already possesses the requisite structure and capacities as a result of their considerable training history. This is a notion supported consistently within the literature (27,43,47,53). At this point, using specific strength training and/or imposing overload through variation may be a useful adjunct to create transfer links (learn to apply newly established capacities in the skill) in line with Newell's (34) model of constraints. However, the mechanisms underpinning transfer are not fully understood, so relying completely on this approach alone is not recommended because the risk of ill-preparing an athlete is high. Should the integration of coordinative overload tasks be deemed appropriate, coaches are advised to discuss the design of these tasks with the technical coach, and in fact carefully consider whether they may be better placed to implement this.

It could be argued that any form of specific training (regardless of overload approach) does not offer the side effects associated with general strength training (development of structure and capacities) that may be equally performance-enhancing for some. Furthermore, although perhaps outside the scope of this article, it is important to recognize that there is only a narrow bandwidth of exercises that are very specific to the target task, and repetition of these may exhaust the limits of biological adaptation on both a local tissue and systemic level (consistent with the multidimensional nature of the syndrome) (27). In other words, the problem of specificity could be replaced by the problem of overtraining (27). This is much less likely to occur with a mixed-methods approach where the coach may use both general and specific training. Accordingly, a mixed-methods approach accounting for the evolving status of the athlete is recommended. This will give the coach the best chance of navigating the overload-specificity paradox, minimizing inevitable programming errors given the highly individual response to training. It is important for future research not to overlook the value of case-study designs because observing cause and effect on an individual basis could aid our understanding of the mechanism's underpinning transfer, and how they interact with variables such as athlete status.

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