Instability resistance training (IRT) is frequently utilized for performance enhancement, rehabilitation, and overall musculoskeletal health. It can involve unstable conditions with body mass or external loads (eg, dumbbells, barbells) as resistance. Instability can be induced with Swiss or BOSU balls (Team BOSU, Ashland, Ohio; a hemispheric inflated ball that is flat on one side and convex on the other), foam rollers, wobble boards, suspended chains, ropes, and bands. Natural surfaces (sand and gravel) can also provide an unstable training surface. Reducing the base of support (bipedal to unipedal stance) will also provide a challenge to the equilibrium (eg, 1-legged squats, Bulgarian squats). Unstable environments such as water can also provide a challenge to postural and joint stability. Unilateral resistance provides a disruptive torque to the body, contributing to instability challenges. Unilateral exercises may be more beneficial than bilateral exercises under the principle of training specificity since the majority of daily living, occupational, and sport activities are unilateral. Greater erector spinae activation occurs during the unilateral shoulder press and increased abdominal activity with the unilateral chest press. Unilateral contractions can also stimulate neural activity in the contralateral limb known as cross-education. Crossover fatigue can occur from a unilateral exercise in the contralateral limb. By training unilaterally, the ipsilateral and contralateral limbs receive neural stimulation while activating the core muscles. Trunk or core training is vital for the transfer and generation of torque and power.

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instability. To successfully lift increased resistance with these exercises, core (trunk) stability and balance must be developed. The Canadian Society for Exercise Physiology indicates that there are functional health benefits to IRT.

**BALANCE TRAINING**

There are 2 components to IRT: progressive challenges to balance and the addition of load or resistance. Strength and power improvements are not derived from increases in muscle mass (hypertrophy) alone. Neural adaptations are a primary component of the early stages of strength development. Balance and stability can improve with strength and power. Recreationally active, university-aged participants underwent balance training for 5 weeks with no resistance. Following training (wobble board test), static balance scores improved by 33%, but more surprising, vertical jump height increased over 9%. The underlying mechanism may be a decrease in postural sway. Since the body acts as an inverted pendulum, an individual with poor balance may have a vertical jump takeoff with a significant horizontal component (postural sway). Balance training may allow a greater vertical component. Hence, vertical jump height may improve without changes in muscle mass or motor unit recruitment. There is a significant correlation between static balance scores (wobble board) and maximum skating velocity in ice hockey players (age range, 15-17 years). Improved balance can augment efficiency of movement and improve performance.

Balance training (without resistance) can improve proprioception. Studies on balance-only training report measures improved by 10% with an effect size of 1.2. These improvements reduce the incidence of accidents (falls) and improve strength, power, and running. Functional performance improved by 31% with an effect size of 0.58. Without strength or power training, functional performance can be enhanced with balance training.

Youth resistance training programs should include balance exercises for optimal performance and prevention of athletic injuries because balance and coordination are not fully developed in children.

**EFFECT OF IRT ON MUSCLE ACTIVATION**

Chest press, push-ups, and squats on an unstable surface will increase core activation to maintain control. Greater trunk activation occurs in water, decreasing postural stability. An extensive review reported that when exercises are performed under unstable conditions, trunk muscle activation increased by 47.3%, with an effect size of 2.5. Greater instability can result in a decrease in muscle activation. For example, a 70.5% drop in leg extension force in an extremely unstable environment was implemented versus a 20.2% decrease with a plantar flexion exercise on a moderately unstable surface. Quadriceps activation decreased with extreme instability by 40.3%, while plantar flexors activation decreased 3% on a moderately unstable surface. To achieve or maintain sufficient muscle activation, the degree of instability should be moderate. Performing exercises while unstable may hamper strength and power development, while instability resistance with lower forces may enhance trunk and limb activation.

The core is the kinetic link that facilitates the transfer of torques and angular momentum between the lower and upper extremities. Specifically, torques and angular momentum are transferred sequentially across the pelvic girdle, trunk, dominant shoulder girdle, and dominant upper extremity. Weakness in the core musculature may interrupt this transfer. In such cases, muscles of the upper limb may attempt to compensate with greater torque production, which can result in overuse injuries. Therefore, training strategies should eliminate weak links in the kinetic chain, particularly in the core musculature.

There is compelling evidence that traditional resistance training exercises with typical resistance (ie, 70% to 80% of 1 RM) produces greater activation of the erector spinae muscles than unstable callisthenic exercises. Greater rectus abdominis and transversus abdominis/internal oblique activity and no significant differences for the external obliques and erector spinae occur with overhead press under stable conditions versus that on a BOSU ball.

A moderately unstable environment allows lower external forces during injury recovery. IRT ensures high muscle activation with lower force or torque on joints. However, for optimal strength or power development, high resistive forces must be employed on the neuromuscular system to ensure a strong training response.

**EFFECT OF IRT ON FUNCTIONAL PERFORMANCE**

The primary basis for traditional ground-based free weights over IRT for athletes is the significant force reduction that occurs when one performs force or power exercises under unstable conditions. With IRT exercises performed under unstable conditions, the mean force and power decreased 29.3%, with an effect size of 2.1.

Not all IRT exercises uniformly demonstrate force deficits. Yet, minor deficits in force, power, and velocity (6% to 10%) occurred with a dynamic bench press performed on a physioball. Less significant reductions in force with Swiss ball chest press exercises may be attributed to the compression or flattening of the ball, with higher resistance contributing to a more stable platform.

Instability exercises may adversely affect movement velocity and range of motion during performance of a squat. Force, power, and high-velocity movement are strongly related to balance and stability. If balance and stability can be improved, strength and power may also increase.

**IRT TRAINING**

IRT studies have reported substantial gains comparable with those achieved with traditional resistance training programs. However, these studies did not involve highly trained athletes.
Training specificity suggests that those who train with unstable environments would perform better under unstable conditions. Instability-trained participants may exert greater forces in an unstable environment.49

**IRT MECHANISMS**

Greater core and limb muscle activation with moderate degrees of instability ensures increased slow- and fast-twitch muscle fiber activation, even when relatively lower forces or power are employed.25 Coordination of the core muscles may be as or more important than the degree of trunk muscle activation for health and performance.7 Deep trunk stabilizers (eg, transversus abdominus and multifidus) respond with anticipatory postural adjustments to movements of the upper or lower limbs.28-30 The activation of stabilizing muscles precedes force application when unstable.37,48 A delayed reflex response of trunk muscles is a risk factor for low back injuries in athletes.57

The sensitivity of afferent feedback pathways can be improved with balance and motor skill training,16,49 resulting in quicker activation of stabilizing muscles.2 IRT may promote co-contractions with shorter latency periods that allow more rapid stiffening and protection of joints.5,43,51 Co-contraction (antagonist) activity increases on unstable surfaces.6,22,41 The role of the antagonist is to control limb position, increase joint stiffness,54 and provide stability.3,51

**CONCLUSION**

Instability conditions can impair force, power, and movement velocity while maintaining similar or providing greater core and limb muscle activation. To exert explosive power, a stable base and strong core are necessary (Table 1). Thus, IRT is highly recommended for youth, elderly, and recreationally active individuals and can be judiciously implemented into the training programs of highly trained athletes (eg, warm-ups and lower load phases of the periodized program).

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**Table 1. Summary of instability resistance training findings**

| Examples of instability exercise modes | Postures: unilateral and unipedal |
|---------------------------------------|----------------------------------|
|                                       | Surfaces: sand, gravel, water |
|                                       | Platforms: balls, wobble/rocker boards |
|                                       | Devices: suspension chains, ropes, rubber bands, water-filled dumbbells |

| Training specificity adherence | Unstable athletic and work environments necessitate unstable training environments |
|-------------------------------|------------------------------------------------------------------|
| Training specificity discordance | Lack of velocity, range of motion, and resistive load specificity with instability resistance training |
| Balance (only) training responses | ↑ Balance and proprioception (large magnitude) |
|                                   | ↑ Functional performance (moderate magnitude) |

| Instability resistance training | ↑ Trunk and limb muscle activation with moderate levels of instability (large magnitude) |
|--------------------------------|↓ Trunk and limb muscle activation with high levels of instability (large magnitude) |

| Effects on functional performance | ↓ Force, power, and movement velocity (large magnitude) |

| Training studies | Large magnitude improvements similar in extent to traditional stable training with recreationally active and sedentary populations |

| Training adaptation mechanisms | ↑ Anticipatory postural adjustments, muscle activation with moderate instability, proprioception, co-contractions |
|-------------------------------|↓ Postural sway |
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