[Sports Physical Therapy]

Instability Resistance Training Across the Exercise Continuum

David G. Behm, PhD,*† and Juan Carlos Colado Sanchez, PhD‡

Context: Instability resistance training (IRT; unstable surfaces and devices to strengthen the core or trunk muscles) is popular in fitness training facilities.

Objective: To examine contradictory IRT recommendations for health enthusiasts and rehabilitation.

Data Sources: A literature search was performed using MEDLINE, SPORT Discus, ScienceDirect, Web of Science, and Google Scholar databases from 1990 to 2012.

Study Selection: Databases were searched using key terms, including "balance," "stability," "instability," "resistance training," "core," "trunk," and "functional performance." Additionally, relevant articles were extracted from reference lists.

Data Extraction: To be included, research questions addressed the effect of balance or IRT on performance, healthy and active participants, and physiologic or performance outcome measures and had to be published in English in a peer-reviewed journal.

Results: There is a dichotomy of opinions on the effectiveness and application of instability devices and conditions for health and performance training. Balance training without resistance has been shown to improve not only balance but functional performance as well. IRT studies document similar training adaptations as stable resistance training programs with recreationally active individuals. Similar progressions with lower resistance may improve balance and stability, increase core activation, and improve motor control.

Conclusion: IRT is highly recommended for youth, elderly, recreationally active individuals, and highly trained enthusiasts.

Keywords: strength training; power; balance; core training; trunk

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.[17]

Unilateral resistance provides a disruptive torque to the body, contributing to instability challenges.[7-10] 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.[45,47] Greater erector spinae activation occurs during the unilateral shoulder press and increased abdominal activity with the unilateral chest press.[12] Unilateral contractions can also stimulate neural activity in the contralateral inactive limb known as cross-education.[33] Crossover fatigue can occur from a unilateral exercise in the contralateral limb.[43,50,58] By training unilaterally, the ipsilateral and contralateral limbs receive neural stimulation while activating the core muscles.[43,50,58] Trunk or core training is vital for the transfer and generation of torque and power.

Proponents of IRT cite training specificity[13]; to compete successfully on unstable surfaces (eg, muddy fields, water, ice), the individual must train in similar environments. Traditional ground-based resistance training exercises, such as squats, deadlifts, and Olympic lifts, possess a moderate degree of

From the †Memorial University of Newfoundland, St John's, Canada, and the ‡University of Valencia, Valencia, Spain

*Address correspondence to David Behm, PhD, Associate Dean of Graduate Studies and Research, School of Human Kinetics and Recreation, Memorial University of Newfoundland, St John's, A1C 5S7, Canada (e-mail: dbehm@mun.ca).

The authors report no potential conflicts of interest in the development and publication of this manuscript.

DOI: 10.1177/1941738113477815

instability.[7-10,26] To successfully lift increased resistance with these exercises, core (trunk) stability and balance must be developed. The Canadian Society for Exercise Physiology[8] 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.[5] Neural adaptations are a primary component of the early stages of strength development.[5] Balance and stability can improve with strength and power. Recreationally active, university-aged participants underwent balance training for 5 weeks with no resistance.[35] 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,[27] 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).[14] Improved balance can augment efficiency of movement and improve performance.

Balance training (without resistance) can improve proprioception.[5,54] Studies on balance-only training report measures improved by 105% with an effect size of 1.2.[7] 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.[11,53]

EFFECT OF IRT ON MUSCLE ACTIVATION

Chest press,[1,3,52] push-ups,[32,44] and squats[42] on an unstable surface will increase core activation to maintain control.[25] Greater trunk activation occurs in water, decreasing postural stability.[17] 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.[7] 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.[6] 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.[7-10]

The core is the kinetic link that facilitates the transfer of torques and angular momentum between the lower and upper extremities.[9] Specifically, torques and angular momentum are transferred sequentially across the pelvic girdle, trunk, dominant shoulder girdle, and dominant upper extremity.[9] 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.[9] 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.[19,26,46] 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.[56]

A moderately unstable environment allows lower external forces during injury recovery.[15] 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.[39]

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.[55] With IRT exercises performed under unstable conditions,[7] the mean force and power decreased 29.3%, with an effect size[18] of 2.1.

Not all IRT exercises uniformly demonstrate force deficits.[20,24] Yet, minor deficits in force, power, and velocity (6% to 10%) occurred with a dynamic bench press performed on a physioball.[38] 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.[7,9,10]

Instability exercises may adversely affect movement velocity and range of motion during performance of a squat.[23] 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.[7,21,36,49] However, these studies did not involve highly trained athletes.

Table 1. Summary of instability resistance training findings

Examples of instability exercise modes	*Postures*: unilateral and unipedal *Surfaces*: sand, gravel, water *Platforms*: balls, rollers, 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	
Effects on muscle activation	↑ 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

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,[16,40] 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.[9,41,51] Co-contractile (antagonist) activity increases on unstable surfaces.[6,22,41] The role of the antagonist is to control limb position, increase joint stiffness,[34] and provide stability.[4,31]

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).

REFERENCES

1. Anderson K, Behm D. Maintenance of EMG activity and loss of force output with instability. *J Strength Cond Res.* 2004;18(3):637-640.
2. Anderson K, Behm DG. The impact of instability resistance training on balance and stability. *Sports Med.* 2005;35(1):43-53.
3. Arjmand N, Shirazi-Adl A. Biomechanics of changes in lumbar posture in static lifting. *Spine.* 2005;30(23):2637-2648.
4. 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.* 1988;16(2):113-122.
5. Behm DG. Neuromuscular implications and applications of resistance training. *J Strength Cond Res.* 1995;9(4):264-274.

6. Behm DG, Anderson K, Curnew RS. Muscle force and activation under stable and unstable conditions. *J Strength Cond Res.* 2002;16(3):416-422.
7. Behm DG, Colado JC. The effectiveness of resistance training using unstable surfaces and devices for rehabilitation. *Int J Sports Phys Ther.* 2012;7(2):226-241.
8. Behm DG, Drinkwater EJ, Willardson JM, Cowley PM. Canadian Society for Exercise Physiology position stand: the use of instability to train the core in athletic and non-athletic conditioning. *Appl Physiol Nutr Metab.* 2010;35:11-14.
9. Behm DG, Drinkwater EJ, Willardson JM, Cowley PM. The role of instability rehabilitative resistance training for the core musculature. *Strength Condition J.* 2011;33(3):72-81.
10. Behm DG, Drinkwater EJ, Willardson JM, Cowley PM. The use of instability to train the core musculature. *Appl Physiol Nutr Metab.* 2010;35:5-23.
11. Behm DG, Faigenbaum AD, Falk B, Klentrou P. Canadian Society for Exercise Physiology position paper: resistance training in children and adolescents. *Appl Physiol Nutr Metab.* 2008;33(3):547-561.
12. Behm DG, Leonard A, Young W, Bonsey A, MacKinnon S. Trunk muscle EMG activity with unstable and unilateral exercises. *J Strength Cond Res.* 2005;19(1):193-201.
13. Behm DG, Sale DG. Velocity specificity of resistance training. *Sports Med.* 1993;15(6):374-388.
14. Behm DG, Wahl MJ, Button DC, Power KE, Anderson KG. Relationship between hockey skating speed and selected performance measures. *J Strength Cond Res.* 2005;19(2):326-331.
15. Bompa T. *Periodization: Theory and Methodology of Training.* Champaign, IL: Human Kinetics Publishers; 2000:113-185.
16. Borghuis J, Hof AL, Lemmink KA. The importance of sensory-motor control in providing core stability: implications for measurement and training. *Sports Med.* 2008;38(11):893-916.
17. Borreani SC, Colado JC, Furio J, Martin F, Benavent J, Madera X. Upper extremity and core muscle activation during an aquatic resistance exercise performed at different depths. *Med Sci Sports Exerc.* 2012;44(5):1866.
18. Cohen J. *Statistical Power Analysis for the Behavioural Sciences.* Toronto, Canada: Ontario University Press; 1988.
19. Colado JC, Pablos C, Chulvi-Medrano I, Garcia-Masso X, Flandez J, Behm DG. The progression of paraspinal muscle recruitment intensity in localized and global strength training exercises is not based on instability alone. *Arch Phys Med Rehabil.* 2011;92(11):1875-1883.
20. Cowley PM, Swensen TS, Forzo GA. Efficacy of instability resistance training. *Int J Sports Med.* 2007;28(10):829-835.
21. Cuğ MAE, Özdemir RA, Korkusuz F, Behm DG. The effect of instability resistance training on knee joint proprioception and core strength. *J Sci Sports Med.* 2012;11:468-474.
22. De Luca CJ, Mambrito B. Voluntary control of motor units in human antagonist muscles: coactivation and reciprocal activation. *J Neurophysiol.* 1987;58(3):525-542.
23. Drinkwater E, Pritchett E, Behm DG. Effect of instability and resistance on unintentional squat: lifting kinetics. *Int J Sports Physiol Perform.* 2007;2:400-413.
24. Goodman CA, Pearce AJ, Nicholes CJ, Gatt BM, Fairweather IH. No difference in 1 RM strength and muscle activation during the barbell chest press on a stable and unstable surface. *J Strength Cond Res.* 2008;22(1):88-94.
25. Grenier SG, Vera-Garcia FJ, McGill SM. Abdominal response during curl-ups on both stable and labile surfaces. *Phys Ther.* 2000;86(6):564-569.
26. Hamlyn N, Behm DG, Young WB. Trunk muscle activation during dynamic weight training exercises and isometric instability activities. *J Strength Cond Res.* 2007;21(4):1108-1112.
27. Hay JG. *The Biomechanics of Sports Techniques.* 3rd ed. Philadelphia, PA: Lippincott & Williams; 1985:75-77.
28. Hodges PW, Richardson CA. Delayed postural contraction of transversus abdominis in low back pain associated with movement of the lower limb. *J Spinal Disord.* 1998;11(1):46-56.
29. Hodges PW, Richardson CA. Inefficient muscular stabilization of the lumbar spine associated with low back pain. *Spine.* 1996;21(22):2640-2650.
30. Hodges PW, Richardson CA. Relationship between limb movement speed and associated contraction of the trunk muscles. *Ergonomics.* 1997;40(11):1220-1230.
31. Hogan N. Adaptive control of mechanical impedance by coactivation of antagonist muscles. *Intern Electrical Engineer J.* 1984;29:681-690.
32. Holtzmann M, Gaetz M, Anderson G. EMG activity of trunk stabilizers during stable and unstable push-ups. *Can J Appl Physiol.* 2004;29(suppl):S55.
33. Kannus P, Alosa D, Cook L, et al. Effect of one-legged exercise on the strength, power and endurance of the contralateral leg: a randomized, controlled study using isometric and concentric isokinetic training. *Eur J Appl Physiol.* 1992;64:117-126.
34. Karst GM, Hasan Z. Antagonist muscle activity during human forearm movements under varying kinematic and loading conditions. *Exper Brain Resh.* 1987;67:391-401.
35. Kean CO, Behm DG, Young WB. Fixed foot balance training increases rectus femoris activation during landing and jump height in recreationally active women. *J Sports Sci Med.* 2006;5:138-148.
36. Kibele A, Behm DG. Seven weeks of instability and traditional resistance training effects on strength, balance and functional performance. *J Strength Cond Res.* 2009;23(9):2443-2450.
37. Kornecki S, Kebel A, Siemienski A. Muscular cooperation during joint stabilization, as reflected by EMG. *Eur J Appl Physiol.* 2001;85(5):453-461.
38. Koshida S, Urabe Y, Miyashita K, Iwai K, Kagimori A. Muscular outputs during dynamic bench press under stable versus unstable conditions. *J Strength Cond Res.* 2008;22(5):1584-1588.
39. Kraemer WJ, Fleck S. Resistance training: exercise prescription. *Physician Sports Med.* 1988;16:69-81.
40. Lephart SM, Pincivero DM, Giraldo JL, Fu FH. The role of proprioception in the management and rehabilitation of athletic injuries. *Am J Sports Med.* 1997;25(1):130-137.
41. Marsden CD, Obeso JA, Rothwell JC. The function of the antagonist muscle during fast limb movements in man. *J Physiol.* 1983;335:1-13.
42. Marshall P, Murphy B. Changes in muscle activity and perceived exertion during exercises performed on a swiss ball. *Appl Physiol Nutr Metab.* 2006;31(4):376-383.
43. Martin PG, Rattey J. Central fatigue explains sex differences in muscle fatigue and contralateral cross-over effects of maximal contractions. *Pflugers Arch.* 2007;454(6):957-969.
44. Martins J, Tucci HT, Andrade R, Araujo RC, Bevilaqua-Grossi D, Oliveira AS. Electromyographic amplitude ratio of serratus anterior and upper trapezius muscles during modified push-ups and bench press exercises. *J Strength Cond Res.* 2008;22(2):477-484.
45. McCurdy K, Conner C. Unilateral support resistance training incorporating the hip and knee. *Strength Cond J.* 2003;25(2):45-51.
46. Nuzzo JL, McCaulley GO, Cormie P, Cavill MJ, McBride JM. Trunk muscle activity during stability ball and free weight exercises. *J Strength Cond Res.* 2008;22(1):95-102.
47. Sale DG. Neural adaptation to resistance training. *Med Sci Sports Exerc.* 1988;20(5):135-145.
48. Slijper H, Latash M. The effects of instability and additional hand support on anticipatory postural adjustments in leg, trunk, and arm muscles during standing. *Exp Brain Res.* 2000;135(1):81-93.
49. Sparkes R, Behm DG. Training adaptations associated with an 8 week instability resistance training program with recreationally active individuals. *J Strength Cond Res.* 2010;24(7):1917-1924.
50. Todd G, Petersen NT, Taylor JL, Gandevia SC. The effect of a contralateral contraction on maximal voluntary activation and central fatigue in elbow flexor muscles. *Exper Brain Res.* 2003;150(3):308-313.
51. Tyler AE, Hutton RS. Was Sherrington right about co-contractions? *Brain Res.* 1986;370:171-175.
52. Vera-Garcia FJ, Elvira JL, Brown SH, McGill SM. Effects of abdominal stabilization maneuvers on the control of spine motion and stability against sudden trunk perturbations. *J Electromyogr Kinesiol.* 2007;17(5):556-567.
53. Verhagen EA, van der Beek AJ, Bouter LM. An economic evaluation of a proprioceptive balance board training programme for the prevention of ankle sprains in volleyball. *Br J Sports Med.* 2005;39(2):111-115.
54. Waddington G, Seward H, Wrigley T, Lacey N, Adams R. Comparing wobble board and jump-landing training effects on knee and ankle movement discrimination. *J Sci Med Sport.* 2000;3(4):449-459.
55. Willardson JM. The effectiveness of resistance exercises performed on unstable equipment. *Strength Cond J.* 2004;26(5):70-74.
56. Willardson JM, Fontana FE, Bressel E. Effect of surface stability on core muscle activity for dynamic resistance exercises. *Int J Sports Physiol Perform.* 2009;4(1):97-109.
57. Zazulak BT, Hewett TE, Reeves NP, Goldberg B, Cholewicki J. Deficits in neuromuscular control of the trunk predict knee injury risk: a prospective biomechanical-epidemiologic study. *Am J Sports Med.* 2007;35(7):1123-1130.
58. Zijdewind I, Zwarts MJ, Kernell D. Influence of a voluntary fatigue test on the contralateral homologous muscle in humans? *Neurosci Letters.* 1998;253(1):41-44.