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CLINICAL COMMENTARY

THE EFFECTIVENESS OF RESISTANCE TRAINING USING UNSTABLE SURFACES AND DEVICES FOR REHABILITATION

David Behm, PhD[1]
Juan Carlos Colado, PhD[2]

ABSTRACT

Background and Purpose: While the popularity of instability resistance training (resistance training that involves the use of unstable surfaces and devices: IRT) is evident in fitness training facilities, its effectiveness for optimal sport performance training has been questioned. The purpose of this clinical commentary is to explore the resistance training literature, which implements the use of unstable surfaces and devices to determine the suitability of IRT for rehabilitation.

Description of Topic and Related Evidence: The criticism of IRT for athletic conditioning is based on the findings of impaired kinetic measures such as force, power and movement velocity during a bout of IRT compared to traditional resistance training with more stable surfaces or devices. However, these deficits occur concurrently with minimal changes or in some cases increases in trunk and limb muscle activation. Compared to the kinetic deficits that are reported during unstable resistance exercises, the relatively greater trunk muscle activation indicates a greater stabilizing function for the muscles. IRT exercises can also provide training adaptations for coordination and other motor control issues, which may be more important for low back pain rehabilitation than strength or power enhancements.

Relation to Clinical Practice: Improvements in postural stability from balance training without resistance can improve force output which can then lead to a training progression involving an amalgamation of balance and IRT leading to higher load traditional resistance training.

Key words: low back pain, injuries, strength training, balance, injury recovery, injury prevention

[1] Memorial University of Newfoundland St. John's, Newfoundland, CANADA
[2] University of Valencia, Valencia, Spain

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CORRESPONDING AUTHOR
David Behm, PhD
Memorial University of Newfoundland
St. John's, Newfoundland, Canada, A1C 5S7
709-737-3408 (phone)
709-737-3979 (facsimile)
Email: dbehm@mun.ca

BACKGROUND AND PURPOSE

Instability resistance training (IRT) devices are very popular in current training facilities. IRT involves resistance exercises either with body mass as a resistance or external loads (e.g. dumbbells, barbells) that are performed on an unstable surface or using unstable devices. It would be difficult to find a fitness facility without some sort of instability device such as Swiss balls, BOSU® balls (definition: BOth Sides Up, description; a hemispherical inflated ball that is flat on one side and convex on the other), foam rollers, wobble boards, suspended chains, ropes, or other devices. Interestingly, Swiss balls which derived their name from Swiss physical therapists, who were purportedly the first to incorporate these balls (prior to World War II) are not called Swiss balls by Swiss physical therapists. The Swiss use the term physioballs, while the Germans call them pezzi balls. No matter what these balls are labeled, balls and other instability devices presently permeate the fitness and rehabilitation environment. However popularity is not always equated with effectiveness.

The Canadian Society for Exercise Physiology (CSEP) position stand[1] on the use of instability to train the core or trunk musculature does not fully endorse instability training for athletic or sport performance training. They state, "ground based free weights are highly recommended for athletic conditioning of the core musculature as they can provide the moderately unstable environments to augment core and limb muscle activation while still providing maximal or near maximal force and power outputs".[1,p. 111] However, they balance that statement by indicating, "Individuals who are involved with rehabilitation, health-related fitness pursuits or cannot access or are less interested in the training stresses associated with ground based free weight lifts, can also receive beneficial resistance training (RT) adaptations with instability devices and exercises to achieve functional health benefits".[1,p. 111] Thus it is necessary to examine the literature to determine why such delineation is recommended between trained, health enthusiasts and the previously injured recovering population.

The purpose of this clinical commentary is to investigate the resistance training literature that examines the utilization of unstable surfaces and devices when performing resistance exercises either with body mass (callisthenic exercises) or with external loads (e.g. barbells and dumbells) to determine the role of IRT for rehabilitation. Much of the literature has investigated the acute and chronic responses to instability training with healthy, young individuals. Thus, the second purpose of this commentary is to apply these findings regarding the use of IRT to injury prevention and rehabilitation.

EFFECT OF IRT ON FUNCTIONAL PERFORMANCE AND MUSCLE ACTIVATION

The primary basis for the CSEP position stand's advocacy of traditional ground based free weights (e.g. squats, dead lifts, Olympic lifts) over IRT (performing resistance exercises either on an unstable platform or using an unstable implement) for athletes is associated with the predominant literature that demonstrates significant force reductions when performing force or power actions under unstable versus stable conditions. Table 1 illustrates from a sample of instability studies that investigate force or power output during exercises performed under unstable conditions compared to the same exercises performed under stable conditions. Force or power, on average, decreases 29.3% with an effect size[2] of 2.1 indicating a large magnitude of change. As an example, to highlight particular studies, the performance of resistance exercises while sitting or lying on a physioball resulted in decreased force output during leg extension (↓70%)[3], plantar flexion (↓ 20%)[3], and isometric chest press (↓60%).[4] Whereas isometric force tends to be reduced, 1RM isokinetic bench press strength on a physioball compared to a stable bench press was maintained.[5,6] Koshida et al[7] suggested that the statistically significant yet minor deficits in force, power and velocity (6-10%) with a dynamic bench press performed on a physioball may not compromise the training response. Since, Koshida and colleagues[7] used 50% of 1 RM, the possible training effects may be more applicable to power and endurance rather than maximal and hypertrophic strength training. In addition to instability-induced force and power deficits, instability exercises have been shown to adversely affect movement velocity and range of motion when performing a squat.[8] Hence the ability to exert force, power or move at high velocity is strongly related to an indi-

Table 1. *Sample of Force and Performance Data Comparing Stable to Unstable Conditions.*

Authors(s)/Year	n	Intervention	% change	Effect Size
Kornecki and Zschorlich 1994[96]	12	Pushing action with varying degrees of freedom (force)	-20%	1.93
		Pushing action with varying degrees of freedom (power)	-40%	2.22
Behm et al. 2002[22]	8	Leg extension MVC force under stable versus unstable conditions	-70.50%	5.6
		Plantar flexion MVC force under stable versus unstable conditions	-20.20%	1.6
Anderson and Behm 2004[97]	10	Bench press under stable versus unstable conditions	-59.60%	5.2
McBride et al. 2006[98]	9	Isometric squat peak force output in stable vs. unstable conditions	-83.80%	2.48
		MVC squat force output in stable vs. unstable	-82.90%	3.9
Sparkes and Behm 2010[15]	18	Bench press under stable versus unstable conditions	-42%	1.7
Drinkwater et al. 2007[8]	14	Squat power under stable and unstable conditions	-24%	3.8
		Squat concentric force under stable and unstable conditions	-18%	3.8
Cowley et al. 2007[99]	14	Work capacity of barbell chest press on stable versus unstable ball pre-training	-12%	0.5
		Work capacity of barbell chest press on stable versus unstable ball post-training	-3.70%	0.01
		Strength of barbell chest press on stable versus unstable ball pre-training	2%	0.5
		Strength of barbell chest press on stable versus unstable ball post-training	0.70%	0.16
Koshida et al. 2008[100]	20	Peak power during dynamic bench press under stable vs. unstable conditions	-12.50%	0.61
		Force during dynamic bench press under stable vs. unstable conditions	-6.20%	0.23
		Velocity during dynamic bench press under stable vs. unstable conditions	-11%	0.62
Goodman et al. 2008[101]	13	Bench press 1 RM strength under stable versus unstable conditions	-0.50%	0.06
Kohler et al. 2010[102]	30	10 RM shoulder press strength under stable load/stable surface vs. unstable load/unstable surface	-30%	0.72
Chulvi-Medrano et al. 2010[103]	31	Deadlift force differences under stable vs. unstable conditions	-52.60%	7.46
Total	**179**	**Mean**	**-29.3%**	**2.155**

vidual's balance and stability when performing the task. For example, Behm et al[9] reported a significant correlation of 0.65 between a static balance measure (number of contacts with the floor while balancing on a wobble board) and maximum skating speed with young hockey players. In other words, if an individual can improve their balance and stability then strength and power may increase as well.

Adhering to the concept of training specificity,[10] balance only training studies (without resistance) have generally been very successful at improving measures of balance and proprioception. Table 2 demonstrates from a sample of balance only training studies (without resistance) that balance and proprioception measures improved by 105% with an effect size of 1.2 indicating a large magnitude of change. Improvements in balance and proprioception not only provide positive benefits for reducing the incidence of accidents such as falls but also improve functional performance measures such as strength, power, running, and other activities. Table 3 results demonstrate that balance training alone with no strength, power, or functional training on average improved measures of functional performance by 31% with an effect size of 0.58 indicating a moderate magnitude of change. Thus, just by improving balance or postural stability without concomitant RT, functional performance can be enhanced. These findings are of particular importance to the field of rehabilitation when musculoskeletal injuries such as ankle sprains can impede balance and impact functional performance. Furthermore, it is common that early in the rehabilitation process force and power production can be hampered by inflammation, pain, and stiffness and thus a balance only training program may be an important initial phase to ameliorate an individual's strength and power. A balance-training program is a safe and productive first step in the rehabilitation plan, which can then be followed by progressive levels of resistance on unstable surfaces or with unstable devices (IRT).

The question would arise as to whether the subsequent step would be to implement separate balance

Table 2. *Sample of Studies Examining the Effect of Balance Training on Balance and Stability.*

Authors(s)/Year	n	Intervention	% change	Effect Size
Tsang et al. 2003[84]	42	Comparison of static standing and limits of stability tests for maximum excursion between elderly control and Tai Chi subjects	13%	1.09
Stanton et al. 2004[104]	18	Swill ball training (6 weeks) on Sarhmann test of core stability	450%	2.88
Bruhn et al. 2004[105]	33	Sensorimotor training on postural stabilisation	6.8%	0.1
Li et al. 2004[106]	188	Functional balance measures on the Berg balance scale with 12 month study period	7.90%	-
Gioftsidou et al. 2006[107]	13	Balance training (12 weeks) on Instability index	51%	1.11
Kean et al. 2006[108]	24	Static balance time with fixed foot balance training	9.50%	0.57
Yaggie et al. 2006[109]	36	Balance training effects on balance	68.5%	1.43
Nagy et al. 2007[110]	19	8 week balance training on anteroposterior path of elderly	1.30%	0.18
		8 week training on mediolateral sway path of elderly	30.00%	4.17
Spennewyn 2008[111]	30	Balance outcomes in fixed resistance equipment	49%	-
		Balance outcomes in free form resistance equipment	245%	-
Panics et al. 2008[112]	20	Pproprioception training on knee joint position	170.90%	-
Sato et al. 2009[113]	20	Core Strength training on Star Excursion balance	11	0.82
Schilling et al. 2009[114]	19	Comparisons of activity-specific balance confidence pre and post intervention	4.10%	0.96
Kibele & Behm 2009[14]	40	7 weeks of instability training and traditional resistance training on balance testing on a wobble board: static balance	4.40%	1.5
Kibele & Behm 2009[14]	40	7 weeks of instability training and traditional resistance training on balance testing on a balance beam: dynamic balance	14.70%	0.67
Granacher et al. 2011[115]	30	Balance training on postural sway in 6-7 year olds	7.80%	0.21
		Balance training on CMJ with 6-7 year olds	5.90%	0.32
Granacher et al. 2011[116]	32	Combined balance & strength training on center of pressure displacement in middle-aged adults	11.70%	0.42
Ogaya et al. 2011[117]	23	Wobble board training (9 weeks) in the elderly: standing on the wobble board	113%	1.17
Muelbauer et al. 2011[118]	20	Center of pressure: Firm ground, eyes open vs foam ground, eyes open for two-legged stance	65.20%	2.71
		Center of pressure: Firm ground, eyes open vs foam, eyes open for step stance condition	32.10%	1.71
		Center of pressure: Firm ground, eyes open vs foam, eyes open for tandem stance condition	26.30%	1.2
		Center of pressure: Firm ground, eyes open vs foam, eyes open for one-legged stance condition	28.60%	1.64
Total	**647**	**Means**	**105%**	**1.243**

and stable RT exercises programs or to attempt to incorporate both balance (stability) and resistance into the same exercises (IRT). Based on the predominant instability-induced decreases in force, power and velocity (Table 1) when compared to traditional stable RT exercises, it has been suggested that trained athletes need a greater adaptive stimuli (force, velocity, and rate of force production)[11,12] which may not achieve the training threshold when performed on unstable devices.[13] However, a number of IRT studies have reported substantial training gains that in some cases were comparable to those achieved with traditional stable RT programs. Table 4 demonstrates that IRT programs achieved on average 22% gains in functional performance measures with an effect size of 0.98 indicating a large magnitude of change with 4-10 weeks of training. For example, untrained individuals involved in seven[14] or eight weeks[15] of either traditional stable

Table 3. *Sample of Studies Examining the Effect of Balance Training on Functional Measures.*

Authors(s)/Year	n	Intervention	% change	Effect Size
Myer et al. 2006[119]	11	Dynamic stabilization and balance training on vertical jump	9.30%	0.75
		Dynamic stabilization and balance training on hamstrings torque	17.40%	0.89
Kean et al. 2006[108]	7	Fixed foot balance training on CMJ height	9.50%	0.57
Yaggie et al. 2006[109]	36	Balance training effects on vertical jump	-0.05%	0.02
		Balance training effects on shuttle run time	3%	0.27
Taube et al. 2007[120]	23	Vertical ground reaction force following sensorimotor training	14.9%	1.01
Oliver et al. 2009[121]	8	Functional balance training in collegiate women volleyball athletes on single leg squats (right)	80.9%	-
		Functional balance training in collegiate women volleyball athletes on single leg squats (left)	141.7%	-
		Functional balance training in collegiate women soccer athletes on single leg squats (right)	32.8%	-
		Functional balance training in collegiate women soccer athletes on single leg squats (left)	4.7%	-
Total	**85**	**Means**	**31.43%**	**0.585**

or IRT found no differences in force, static balance, or functional performance between the groups. All measures improved over time for both the unstable and stable trained groups. In the Sparkes and Behm study,[15] there was a trend (p = 0.08) for the unstable training group to increase unstable forces to a greater extent. In other words, the instability-trained subjects could exert greater forces when experiencing an unstable environment. Since in the every day environment, unstable situations can arise such as slipping on an icy sidewalk, wet grass or a muddy patch, the ability to respond with higher forces could preclude or minimize chances for injury. However, if when performing unstable exercises there is a considerable decrease in force and power output compared to traditional stable exercises, how is it possible that prolonged IRT programs could provide similar strength training enhancements in the short term (i.e. 7-8 weeks) as compared to traditional stable RT programs?

The common finding of instability-induced decreased force or power compared to traditional RT exercises is not always accompanied by a similar impediment in muscle activation. Whether muscle activation is substantially reduced depends on the severity of the unstable condition. Many of the studies in the literature report that the demands of lifting while supported on an unstable surface cause an increase in core muscle activation, in order to maintain control.[16] Increased core muscle activation when performing the same exercises under moderately unstable versus stable conditions has been shown when performing chest press,[4,17,18] push-ups,[19] and squats.[20] Table 5 highlights a sample of studies that examined trunk stabilizer muscle activation when performing exercises under stable and unstable conditions. On average, trunk muscle activation increased by 47.3% with an effect size of 2.48 indicating a large magnitude of change. It should be noted that there is a substantial degree of variability between these studies. For example, Martins et al[21] reported serratus anterior muscle activation deficits ranging from 27-106% when performing push-ups under unstable versus stable conditions. A rationale for these discrepancies is the extent of instability. Studies that implement a higher degree of instability can result in a decrease in muscle activation. For example, Behm et al[22] had subjects perform either a leg extension or plantar flexion resistance exercise while seated on a stable bench or an unstable physioball. When performing the leg extensions, there was only one point of stable contact with the floor making this exercise more unstable compared to the plantar flexion exercise where both feet were in contact with the floor resulting in only moderate instability. Compared to the stable control condition, the more unstable leg extension exercise resulted in a 70.5% drop in leg extension force whereas the less or moderately unstable plantar flexion exercise caused a 20.2% decrease in force.

Authors(s)/Year	n	Intervention	% change	Effect Size
Stanforth et al. 1998[122]	20	10 week resistaball training study on double leg lowering	49.60%	1.17
		10 week resistaball training study on cybex back extension	156.20%	1.98
		10 week resistaball training study on cybex abdominal	94.80%	1.09
Bruhn et al. 2004[105]	33	Sensorimotor training on MVC	6.7%	0.21
		Sensorimotor training on squat jump height	4.6%	0.21
Tsimaras et al. 2004[123]	15	Muscle strength and dynamic balance ability training at 300 deg/s	20%	0.68
		Muscle strength and dynamic balance ability training at 60 deg/s	13.60%	0.41
Bruhn et al. 2006[124]	18	Strength training & sensorimotor training on muscle strength on development of bilateral 1 RM	37.00%	1.11
Carter et al. 2006[40]	20	Stability ball training on static back endurance	30.30%	0.7
		Stability ball training on side bridge test	5.70%	0.52
Gruber et al. 2007[125]	33	Sensorimotor training on MVC	0.53%	0.05
Cowley et al. 2007[99]	14	Instability training using stability ball platform on 1RM strength during barbell chest press exercise	15.50%	3.1
		Instability training using flat bench platform on 1RM strength during barbell chest press exercise	17.40%	3.8
Thompson et al. 2007[126]	18	Club Head speed results in older golfers after functional training	4.90%	0.53
Cressey et al. 2007[127]	19	10 weeks lower body unstable surface training on Bounce drop jump power	0.8%	0.11
		10 weeks of lower body unstable surface training on CMJ power	0.0%	0
		10 weeks of lower body unstable surface training on 40 yard sprint time	1.8%	0.82
		10 weeks of lower body unstable surface training on T-test times	2.9%	1.33
Cowley et al. 2007[99]	14	Instability resistance training on 1 RM strength during barbell chest-press on a stability ball	15%	3.06
		Instability resistance training work capacity during barbell chest-press on a stability ball	27%	3.02
Kibele et al. 2009[14]	40	7 weeks of instability training and traditional resistance training on strength during leg extension	9.50%	0.32
		7 weeks of instability training and traditional resistance training on shuttle run time	20%	0.2
Sekendiz et al. 2010[128]	21	Swiss ball core strength training on trunk flexor strength	28.50%	1.19
		Swiss ball core strength training on trunk extensor strength	23.60%	0.92
		Swiss ball core strength training on lower limb extensor strength	8.50%	0.44
		Swiss ball core strength training on lower limb flexor strength	36.50%	1.66
Sparkes & Behm 2010[15]	18	Instability resistance training (8 weeks) on MVIC unstable / stable force ratio	21%	1
		Instability resistance training (8 weeks) on CMJ	5.7%	1
		Instability resistance training program (8 weeks) on MVIC forces	23.6%	0.44
Saeterbakken et al. 2011[129]	24	Core stability training on throwing velocity in female handball players	4.90%	0.2
Granacher et al. 2011[116]	32	Combined balance & strength training on CMJ in middle-aged adults	4.10%	0.22
		Combined balance & strength training on plantar flexors MVC in middle-aged adults	19.30%	0.59
		Combined balance & strength training on plantar flexors isokinetic force in middle-aged adults	16.50%	0.49
Total	**339**	**Means**	**22.0%**	**0.98**

Table 4. *Sample of Studies Examining the Effect of Instability Training on Performance Measures.*

Table 5. *Sample of Studies Examining EMG Data Under Stable versus Unstable Conditions - Trunk Stabilizer Muscle Activity.*				
Authors(s)/Year	**n**	**Intervention**	**% change**	**Effect Size**
Vera-Garcia et al. 2000[130]	8	External oblique muscle performing a curl up on a stable bench vs. moderate instability	101.80%	-
		External oblique muscle performing a curl up on a stable bench vs. extreme instability	-15.50%	-
Behm et al. 2005[90]	11	EMG for lumbosacral erector spinae during stable exercises vs. unstable exercises	4.70%	0.59
		EMG for lower abdominal stabilizers during stable exercises vs. unstable exercises	27.90%	0.82
Anderson & Behm 2005[131]	14	EMG activity of the abdominal stabilizer muscles during the smith machine squat vs. unstable squat	29.60%	2.8
		EMG activity of the abdominal stabilizer muscles during the free squat vs. unstable squat	18.60%	2.7
		EMG of the lumbo-sacral erector spinae during the free squat vs. unstable squat	22.90%	4.7
		EMG of the lumbo-sacral erector spinae during the smith machine squat vs. unstable squat	20.00%	6.7
		EMG of the upper lumbar erector spinae during the smith machine squat vs. unstable squat	33.80%	-
		EMG of the upper lumbar erector spinae during the free squat vs. unstable squat	22.90%	-
		EMG of the soleus during the smith machine squat vs. unstable squat	73.10%	16.3
		EMG of the soleus during the free squat vs. unstable squat	58.50%	10.7
Marshall et al. 2006[132]	12	Transversus abdominus during squats performed with a stable surface vs. swiss ball	-56.70%	0.35
Marshall et al. 2006[133]	14	Transversus abdominus with a swiss ball vs. stable surfaces	-57.10%	0.48
Freeman et al. 2006[134]	10	Right erector spinae during push-up: no legs vs. standard	4.50%	0.04
		Left erector spinae during push-up: no legs vs. standard	-85.20%	2.3
Norwood et al. 2007[135]	15	Latissimus dorsi under stable and dual instability conditions	180.50%	0.98
		Erector spinae under stable and dual instability conditions	875.90%	1.9
Sternlicht et al. 2007[136]	41	Stability ball crunch with a traditional crunch on upper rectus muscle	-30.70%	0.44
Bressel et al. 2009[137]	12	50% of 1RM vs. BOSU trainer with free weight squat exercise on transversus/internal oblique	-12.70%	0.28
		50% of 1RM vs BOSU trainer with the free weight squat exercise on erector spinae	10.70%	0.21
Willardson et al. 2009[26]	12	Transverse abdominus/internal oblique activity for Back Squat stable 50% of 1RM vs. BOSU 50% of 1RM	-26.90%	0.64
		Erector spinae activity for Back Squat stable 50% of 1RM vs. BOSU 50% of 1RM	14.50%	0.34
Schwanbeck et al. 2009[138]	6	Erector spinae with a free weight squat to smith machine squat	-45.50%	0.59
Kohler et al. 2010[102]	30	Lower erector spinae with a shoulder press under unstable load/unstable surface vs. stable load/stable surface conditions	24%	0.24
		Upper erector spinae with a shoulder press under unstable load/unstable surface vs. stable load/stable surface conditions	37%	0.49
Total	**185**	**Means**	**47.33%**	**2.48**

Whereas quadriceps activation diminished 40.3% (highly unstable), plantar flexor activation remained relatively stable with an insignificant decrease of 2.9% (moderately unstable). Therefore, to achieve or maintain a sufficient extent of muscle activation, the degree of instability should be moderate rather than high. For example, while standing on a physioball may be an impressive feat of balance, attempting to perform resistance exercises at the same time would result in low muscle activation levels.

Contrary to studies that report greater core muscle activation when comparing similar unstable exercises to stable exercises with similar absolute resistance, there is compelling evidence that traditional RT exercises such as squats and dead lifts with typical strength training resistance (i.e. 70-80% of 1 RM) produced greater activation of the erector spinae muscles versus unstable callisthenic exercises.[23,24,25] Willardson et al[26] reported greater rectus abdominis and transversus abdominis/internal oblique activity and no significant differences for the external obliques and erector spinae when performing an overhead press with 75% of 1RM under stable conditions versus 50% of 1-RM on a hemispherical BOSU® ball. In summary, Willardson and colleagues[26] did not report any advantage for core activation when training with a hemispherical BOSU® ball. However, it is sometimes difficult to entice recreational or novice fitness enthusiasts or persons involved in rehabilitation to consistently train with loads equal to 75-80% or more of their 1 RM. For these individuals, the lower force and comparable EMG activity under unstable conditions may help in their motivation to adhere to a training program.

Based on the near linear force-EMG relationship, muscle activation correlates well with force output.[27] If with moderate instability, force is depressed but activation is not substantially affected; according to the force-EMG relation, there must be a force component missing. The similar extent of muscle activation accompanied by decreased force with instability exercises when compared to traditional RT exercises suggests that the dynamic motive forces of the muscles (the ability to apply external force) may be transferred into greater stabilizing functions (greater emphasis on isometric contractions).[4] Again this would be beneficial for rehabilitation purposes as it is inadvisable to force a recuperating weaker muscle to exert extremely high forces. However, according to the orderly recruitment of motoneuron concept,[28] low intensity contractions tend to predominantly activate the lower threshold, slow twitch, type I fibres. For rehabilitation purposes, it may be more productive if a greater spectrum of muscle fibers could be activated and subjected to healthy stress to accelerate the recovery process. The use of a moderately unstable environment would allow the combination of lower external forces to be placed on the recuperating muscles albeit with a relatively higher degree of activation, which through both motive and stabilizing functions would provide positive training adaptations for a wider range of muscle fibers.[29] These positive training adaptations may apply to the prevention and recuperation of both core (trunk) and limb injuries and in cases of degeneration.

EFFECT OF INSTABILITY ON CO-CONTRACTIONS

Generally, co-contractile activity increases when training on unstable support surfaces.[22] The role of the antagonist under unstable or uncertain conditions would primarily be to control the position of the limb when producing force. Antagonist activity is reported to increase when uncertainty exists in the task.[30,31] Increased antagonist activity may also be present to increase joint stiffness[32] and hence stability.[33] Furthermore, co-contractions are important for joint protection[34] in order to safeguard joints from excessive forces.[35]

While increased antagonist activity could be utilized for joint and muscle protection, to improve motor control, balance,[36] and mechanical impedance (opposition to a disruptive force),[33] it would also contribute to force deficits during unstable conditions by providing greater resistance to the intended motion. However, continued training may result in less co-activations.[37] The instability-induced higher muscle activation and co-contractions while exerting lower force which could be an advantage for rehabilitating injuries such as sprains and strains, might not be as appropriate for some other conditions such as osteoarthritis. Based on the assumption of near linear force-EMG relations,[27] the high muscle activation should produce similar amounts of internal force production. In conjunction with instability-induced greater co-contractions, internal muscle and joint tension could be high which could lead to compressional pain with an arthritic joint. Hence, caution should be used if recommending IRT in a rehabilitation setting for those with osteoarthritis, as internal muscle tension may remain high.

LOW BACK PAIN (LBP)

A strong trunk or core provides a base for the torques generated by the limbs when performing daily and athletic activities.[29] Reeves and colleagues[38] explained that training the core musculature improves the robustness of the stabilizing system, potentially protecting against low back injuries. Durall et al[39] indicated that there were no new incidences of low back pain (LBP) reported in collegiate gymnasts that participated in a 10-week core muscle-training program that incorporated progressive manual loading of the side bridge and prone back extension exercises in addition to their normal trunk flexion exercises. The progressive application of IRT exercises may play a strategic role with the prevention and treatment of LBP.[39,40] Specific training to ameliorate the stabilizing functions of spinal muscles is an important factor in the rehabilitation of LBP.[41] Increased strength of low back muscles is not the most important consideration for the prevention of LBP.[42-44] However, increased strength can provide some protection when higher torques are generated with certain athletic skills or work-related tasks.[45-47] Factors that are more highly correlated with LBP are decreased muscular endurance[48,49] and impaired neuromuscular coordination.[50-52] To ensure spinal stability, there must be coordinated activation of the core musculature. Hubley-Kozey et al[53] noted greater consistency with the activation sequences of abdominal wall muscles during a supine bilateral leg-raising task among individuals that were better able to control lumbopelvic motion. This finding was especially apparent during phases of the task in which the hips and knees were extended, creating greater resistive torque.

This coordinated muscle stabilization is vital since the ligaments have limited potential to stabilize the vertebral column. Lumbar spine ligaments have been reported to fail under compressive loads of approximately 90N,[54] whereas the mass of the body in a standing position exceeds 10,000N during dynamic lifting tasks.[55] Clearly, the ability to withstand these large forces is dependent on additional muscular stabilization. The muscles most responsible for the local stabilization are provided by the local abdominal (e.g. transversus abdominus, internal obliques) and paraspinal (e.g. multifidus) muscles, which increase the stiffness of the spine to enhance stability. These muscles transfer torques and angular momentum during performance of integrated kinetic chain activities such as throwing or kicking.[56-58] Panjabi proposed that an active neural subsystem controls the recruitment of the core musculature with feed-forward and feedback mechanisms.[54,59] Feed-forward mechanisms are pre-planned motor programs in preparation for movement, whereas feedback mechanisms are utilized to fine tune motor programs as skills are performed with greater efficiency over time. The objective of IRT is to stress the feed-forward and feedback systems to reprogram them for healthy and efficient functioning. Hence, the prevention of LBP and in some cases limb and joint injuries can be based on the ability of the core muscles to anticipate and respond to movement in order to stabilize the vertebral system.[41,60]

Since the stiffness of a vertebral joint can be achieved with contractions as low as 25% of MVC[56] and the efficiency of the multifidus can be improved with training loads of 30-40% of MVC,[61] it is unnecessary to use excessive loads. Furthermore, since type I (slow twitch) fibers comprise the majority (>80%) of the erector spinae,[62] multifidus, and longissimus thoracis[63] muscles in healthy males and females, lower loads with higher repetitions should be the most appropriate training stress for the prevention or rehabilitation of low back problems. Even with the instability-induced lower forces outputs (compared to similar stable exercises); the higher instability-induced muscle activation,[13,29] and the use of higher repetitions will ensure an increase in muscle fiber recruitment and eventual activation of higher threshold motor units (type II; fast twitch).[64] Therefore, the low back stabilizing musculature can respond positively to multiple sets that involve high repetitions (e.g. >15 per set) especially under unstable conditions.[1,13] Supporting the body on an unstable surface will elicit an increase in core muscle activation to maintain postural equilibrium during a given exercise.[65] Jorgensen et al[66] demonstrated moderate to high activation levels (i.e. 60-80% MVC) of the rectus abdominis, external oblique abdominis, erector spinae, and trapezius in untrained women that performed progressively more difficult versions of the supine bridge, quadruped, side bridge, and prone plank. These findings suggest that for untrained individuals, the utilization of body mass and manipulation of resistive torque via postural adjustments can sufficiently load the core musculature to increase strength and localize muscular endurance.

EFFECTS OF MOTOR CONTROL ON LOW BACK PAIN (LBP)

Appropriate coordination or motor control of the core muscles may be as or more important than the extent of trunk muscle activation or strengthening in patients with LBP.[50] There are numerous studies that report motor control deficits of the core muscles with patients with LBP.[51,52,67] Deep trunk stabilizers (i.e. transversus abdominus and multifidus) respond with anticipatory postural adjustments (APA) to movements of the upper or lower limbs.[51,52,68] In healthy individuals, the activation of stabilizing muscles precedes the instant of force application.[69,70] Individuals with LBP tend to display delays or disruptions in this protective APA.[51,52] A delayed reflex response of trunk muscles is reported to be a risk factor for low back injuries in athletes.[71] Furthermore, Radebold et al[72] reported that the antagonist muscle group was delayed in contracting while the agonist was delayed in relaxing during quick trunk flexion and extension with chronic LBP. Chronic LBP has also been associated with early or over recruitment of certain stabilizing muscles. Ferguson et al[73] found that the erector spinae with chronic LBP subjects contracted earlier and longer during lifting tasks compared to healthy controls. Exercises that can re-program appropriate anticipatory, concomitant postural adjustments as well as appropriate motor coordination to deactivate the appropriate muscles upon movement completion would be important for the prevention and rehabilitation of LBP.

Furthermore, the sensitivity of afferent feedback pathways can be improved with balance and motor skill training,[67] resulting in quicker onset times of stabilizing muscles.[74] For example, a back extensor rehabilitation-training program of two weeks duration reduced reaction times in patients with LBP to a similar time as that of healthy controls.[75] IRT may promote agonist-antagonist co-contractions with shorter latency periods that allow for rapid stiffening and protection of joint complexes.[13] Thus, exercises that can improve the coordination[50,67,76] and extent[40,77] of core muscular activation potentially enhance the prevention and rehabilitation of LBP as well as accompanying extremity injuries. Traditional RT can accomplish the same muscle activation goals but may necessitate the use of greater resistances. On the other hand, compared to traditional RT exercises, instability-based exercise programs appear to require more complex and difficult movements for ongoing progression.[29] Thus neither stable nor unstable resistance training should be considered as an overall panacea.

PREVENTION OF INJURIES TO THE EXTREMITIES

Neuromuscular control problems can increase the chances for lower back and extremity injuries.[78-81] The incidence of ankle sprains in a group of volleyball players was reduced with balance training,[82] which may be related to the improved discrimination of ankle inversion movements found with wobble board training.[83] Similarly, the use of Tai Chi has been reported to improve knee joint proprioception[84] and functional balance[85] in elderly individuals. IRT exercises have been reported to be effective in decreasing the incidence of LBP and improving the sensory efficiency of soft tissues that stabilize the knee and ankle joints.[40,76,86] The APA used to pre-stiffen joints prior to movement is not unique to the spine and has been shown to occur in peripheral joints as well.[87] The contraction of the upper trapezius, biceps and rotator cuff of the shoulder complex[87] has been shown to occur in anticipation of movement in healthy subjects. Therefore, IRT of the upper body may help to improve stability of the shoulder joint. IRT may improve both muscular balance and strength which may be useful in prevention of sports injuries and also aid in the recuperation of individuals who cannot withstand heavier loads or high resistance.

UNILATERAL TRAINING AS A FORM OF INSTABILITY

Instability can also be achieved without unstable devices such as balls, wobble boards and foam rollers. Typically, resistance exercises are more often bilateral using either a barbell or a pair of dumbbells. However the majority of activities of daily living, occupational tasks and sport actions are unilateral (e.g. tennis, squash, baseball),[88] and thus unilateral exercises may be more beneficial because they adhere to the principle of training specificity.[89] Behm et al[90] reported greater erector spinae activation during the unilateral shoulder press and greater transversus abdominus and internal oblique activity with the unilateral chest press. Rather than using an unstable device, unilateral resisted actions may provide a disruptive torque to the body, thus providing another type of unstable condition. Hence, an effective strategy to activate the spinal stabilizers while training the upper limbs would be to use one dumbbell during the action.[91] Unilateral contractions can also stimulate neural activity in the contralateral but inactive limb, referred to as cross education.[92] Other studies have reported crossover fatigue effects from a unilateral exercise to the same contralateral limb with the leg extensors,[93] biceps brachii,[94] and dorsal interosseus (minor effects).[95] Therefore, by training the contralateral healthy limb, the injured limb will receive neural stimulation and may maintain greater strength, while also stimulating activation of the core muscles.

CONCLUSIONS

Some of the characteristics of IRT exercises that are not conducive to optimal strength or power training for athletes, may be favorable for rehabilitation. The instability-induced deficits in force compared to traditional stable RT exercises, which dampen the strength training stimuli in trained individuals, can be of sufficient intensity for a recuperating muscle. While, these lower external forces exert less, but healthy stress on a more injury-susceptible joint, the less dramatic changes or even increases in trunk and limb muscle activation provide greater stabilizing functions to protect recovering muscles and articulations. Greater coordination training challenges with instability exercises should promote motor control adaptations (i.e. co-activations, anticipatory postural adjustments) that are especially important with LBP conditions. Physical therapists should consider IRT as a progressive component in the rehabilitation training program that may begin with solely balance training (no load), progressing to balance challenges with resistance (IRT) to traditional ground based RT with greater loads and intensities.

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