EFFECTS OF KETTLEBELL TRAINING ON POSTURAL COORDINATION AND JUMP PERFORMANCE: A RANDOMIZED CONTROLLED TRIAL

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ABSTRACT

Jay, K, Jakobsen, MD, Sundstrup, E, Skotte, JH, Jørgensen, MB, Andersen, CH, Pedersen, MT, and Andersen, LL. Effects of kettlebell training on postural coordination and jump performance: A randomized controlled trial. *J Strength Cond Res* 27 (5): 1202–1209, 2013—The aim of this study was to investigate the effectiveness of a worksite intervention using kettlebell training to improve postural reactions to perturbation and jump performance. This single-blind randomized controlled trial involved 40 adults ($n = 40$) from occupations with a high prevalence of musculoskeletal pain and discomfort (mean age 44 years, body mass index 23 $kg \cdot m^{-2}$, 85% women). A blinded examiner took measures at baseline and follow-up. Participants were randomly assigned to a training group—doing kettlebell swings 3 times a week for 8 weeks—or to a control group. The outcome measures were postural reactions to sudden perturbation and maximal countermovement jump height. Compared with the control group, the training group had a significant decreased stopping time after perturbation (−109 ms, 95% confidence interval [−196 to −21]). Jump height increased significantly in the training group (1.5 cm, 95% confidence interval [0.5 to 2.5]), but this was nonsignificantly different from control. Kettlebell training improves postural reactions to sudden perturbation. Future studies should investigate whether kettlebell training can reduce the risk of low back injury in occupations with manual material handling or patient handling where sudden perturbations often occur.

KEY WORDS ballistic, training, kettlebell, fitness, countermovement jump, perturbation

INTRODUCTION

The risk of developing low back pain is multifactorial and can be parsed into 3 main categories: psychosocial, biomechanical, and individual. For example, a poor psychosocial work environment in terms of job dissatisfaction is considered a significant predictor of experiencing low back pain (14,16). The biomechanical factors could include the magnitude of cumulative spinal compression and the frequency of spinal flexion and rotation. Individual factors include age, weight, selected anthropometric measurements, spine abnormalities, and muscular endurance (5). Furthermore, a history of low back pain is one of the best predictors of future back pain for the general working population and for collegiate athletes (5).

Sensory motor amnesia and thereby impaired motor control of the lumbar spine has recently been suggested as a possible predisposing mechanism to low back pain or low back injury (2). In support of these findings, several studies confirm that individuals with low back injury exhibit longer trunk muscle response latencies than healthy controls when exposed to sudden loading (4,7,8,15). In addition, epidemiologic studies suggest that there is a link between low back injury and sudden movements, such as slips and trips (16,17,18,21). Conversely, spinal stability depends on appropriate movement and muscle control, which determine the trunk kinematic response to sudden perturbation and possibly the likelihood of pain onset (5). The probability of an individual to sustain an injury and experience pain is increased if the muscle response to sudden postural loading is inadequate and thereby potentially compromising to the stability of the spine (5). According to Cholewicki et al. (5) and Radebold et al. (26), subjects with low back pain and athletes with an acute low back injury had markedly longer latencies in the offset of agonistic and onset of antagonistic muscles in response to sudden trunk perturbation in flexion, extension, and lateral bending as measured in 12 major trunk muscles during quick force release settings. Stabilization of postural equilibrium is achieved by continuous afferent and efferent control output strategies in the sensorimotor system based on input from visual, vestibular, and proprioceptive

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feedback loops. If any of the visual, vestibular, and proprioceptive feedback loops are providing imprecise information or a loop itself is compromised, postural coordination efforts increase by increasing muscle activity (2,13). Several reviews (1,9,28) report that regular exercise training is an effective means in the treatment of musculoskeletal disorders in the low back and is therefore often prescribed in clinical health care settings as an intervention strategy. Conversely, increased muscle strength of the back extensors may disrupt the balance of the contraction-relaxation performance between the antagonistic muscle pairs and thereby affect postural stability and control strategies negatively. Kollmitzer et al. (13) showed that after 4 weeks of daily back extensor strength training, postural stability had been significantly compromised by an increase in control efforts. In contrast, the same research team found an increase in postural stability after 4 weeks of balance skill training. Other research teams have shown improved postural stability and sensory motor function after typical resistance training and core stabilization exercises (3,20).

Kettlebell training has in recent years grown very popular in the strength and conditioning community and is often claimed to be a superior way of developing explosive power by fitness professionals and strength coaches. However, to our knowledge, no randomized controlled intervention trials have actually investigated this claim. The aim of this study was therefore to investigate the effect of kettlebell training on postural coordination and maximal countermovement jump height (CMJH) hypothesizing a significant positive effect on the 2 parameters as our laboratory has recently shown approximately 50% reductions in low back and neck/shoulder pain after 8 weeks kettlebell training in a group of laboratory technicians with nonchronic musculoskeletal pain (10).

METHODS

Experimental Approach to the Problem

To evaluate the effectiveness of kettlebell training on postural coordination during perturbation and jump performance, we performed a randomized controlled worksite intervention trial in Copenhagen, Denmark, from March to May 2010. After 8 weeks of ballistic kettlebell exercise, computerized posturography and force plate analysis enabled our research team to quantify improvements in posterior whole-body movement after load-release perturbation and maximal jumping height performance, in a group of untrained laboratory technicians.

Subjects

We sent out a screening questionnaire to 174 employees and 90 replied. The inclusion criteria were willingness to participate in the study and absence of the predefined exclusion criteria. This leads to the exclusion of 12 employees based on (a) a medical history of a life-threatening disease ($n = 0$), (b) traumatic injury of the neck or back ($n = 5$), (c) other serious chronic disease ($n = 2$), or (4) pregnancy ($n = 5$). Furthermore, 21 employees declined participation in the study. We invited the remaining 57 employees for a physical examination and 43 showed up. During the physical examination, we excluded 3 employees who had blood pressure above 160/100 mm Hg.

Using a computer-generated random numbers table, we assigned the 40 participants to the training ($n = 20$) or control ($n = 20$) group after a demographic baseline examination, which is shown in Table 1. We kept the examiner blinded and instructed the participants not to reveal to which group they were assigned during follow-up testing.

The Local Ethical Committee approved the study protocol (HC2008103). All participants gave written informed consent in agreement with the Declaration of Helsinki. We registered the study before enrollment of participants (www.clinicaltrials.gov, number NCT01076127).

Procedures

Computerized Posturography and Force Plate Calculations. We used a hard surfaced force platform (Amti model OR6) to measure the center of pressure (CoP) displacement. The force (Fx, Fy, and Fz) and moment (Mx, My, and Mz) signals were sampled at 125 Hz and filtered (10 Hz fourth-order Butterworth zero-phase low-pass filter) (12). The CoP consisting of the anterior-posterior (AP) and medio-lateral (ML) components ($[x_{AP}, x_{ML}] = [Mx/Fz, My/Fz]$) were determined.

The 95% confidence ellipse areas (CEA) were calculated for the CoP as described by Jørgensen et al. (12). In short, the 95% CEA is the area of the 95% bivariate ellipse, enclosing approximately 95% of the points on the CoP path. Confidence ellipse area was calculated as $\pi \cdot a \cdot b$, where the radii of the ellipse were determined as follows:

TABLE 1. Baseline demographics and characteristics of the training ($n = 20$) and control group ($n = 20$).*

	Training	Control
Demographics		
Age, years	44 (8)	43 (10)
Height, cm	169 (7)	172 (9)
Weight, kg	68 (11)	66 (11)
Body mass index, $kg \cdot m^{-2}$	24 (3)	22 (2)
Number of women/men	17/3	17/3
Performance		
Maximal jump height (cm)	17.0 (1.0)	17.6 (1.1)
Perturbation		
Stopping time (ms)	534 (38)	486 (35)
Leisure time physical activity ($h \cdot wk^{-1}$)		
Light	3.0 (1.8)	3.1 (1.6)
Moderate	2.1 (1.4)	2.3 (1.4)
Vigorous	0.2 (0.4)	0.2 (0.4)

*Values are mean (*SD*).

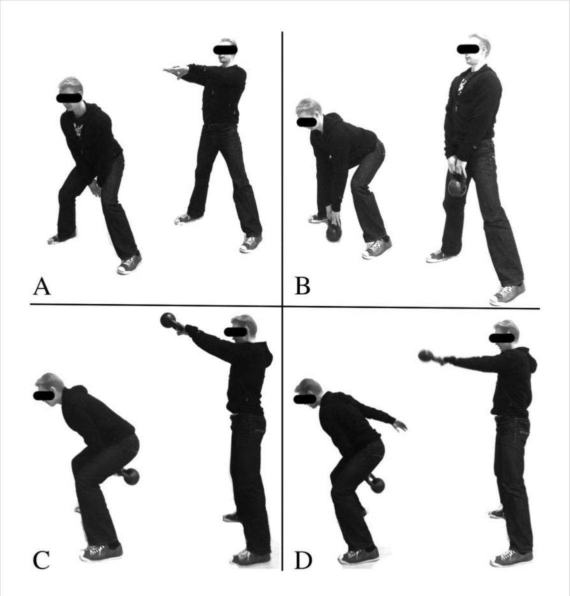

Figure 1. Illustration of the 4 progression levels used during the training sessions. A) Unweighted swing, B) kettlebell deadlift, C) 2-handed kettlebell swing, and D) one-handed kettlebell swing.

$$a = \left(F_{0.05[2,N-2]} \cdot \left(S_{\mathrm{AP}}^2 + S_{\mathrm{ML}}^2 + D\right)\right)^{1/2},$$

$$b = \left(F_{0.05[2,N-2]} \cdot \left(S_{\mathrm{AP}}^2 + S_{\mathrm{ML}}^2 - D\right)\right)^{1/2},$$

where s_{AP} and s_{ML} are AP and ML *SD*s, respectively, of the CoP data, and $F_{0\cdot 05\ [2,N-2]}$ is the F statistic at a 95% confidence level for a bivariate distribution with N data points; $F_{0\cdot 05\ [2,N-2]}$ is approximately 3.0 for large sample sizes ($N > 120$). D is calculated according to the following equation:

$$D = \left(\left(S_{\mathrm{AP}}^2 + S_{\mathrm{ML}}^2\right) - 4 \cdot \left(S_{\mathrm{AP}}^2 \cdot S_{\mathrm{ML}}^2 - S_{\mathrm{APML}}^2\right)\right)^{1/2},$$

where s_{APML} is the covariance

$$S_{\mathrm{APML}} = \frac{1}{N} \sum \left(x_{\mathrm{AP}} - \overline{x_{\mathrm{AP}}}\right) \cdot \left(x_{\mathrm{ML}} - \overline{x_{\mathrm{ML}}}\right)$$

and where $\overline{x_{\mathrm{AP}}}$ and $\overline{x_{\mathrm{ML}}}$ are mean values of the CoP coordinates.

Maximal CMJH was derived from the vertical take-off velocity (Vto) using the equation CMJH = Vto2/(2 g), where $g = 9.82\ \mathrm{ms}^{-2}$. The vertical velocity (V) of the body center of mass was calculated by time integration of the instantaneous acceleration (Fz/m − g, where m = body mass in kilograms, $g = 9.82\ \mathrm{ms}^{-2}$) and body center of mass position was calculated by time integration of V.

Postural Reactions to Perturbation. Postural reactions to perturbation were assessed in 3 single bilateral attempts during a quick force release setting on the force platform as previously described by Jørgensen et al. (12). The participants were instructed to be bare footed while holding a rod at shoulder width and at arms length horizontally out in front of the body. A 2.2-kg load was attached by the examiner to the center of the rod via an electromagnet. Each participant's lever arm, defined as the distance from the lateral point on the acromion to the center of the rod, was measured. A signal from the computer triggered release of the load at a random time between 5 and 15 seconds after test initiation. The release of the load produced a sudden change in external forces acting on the participant, leading to a small AP displacement of the

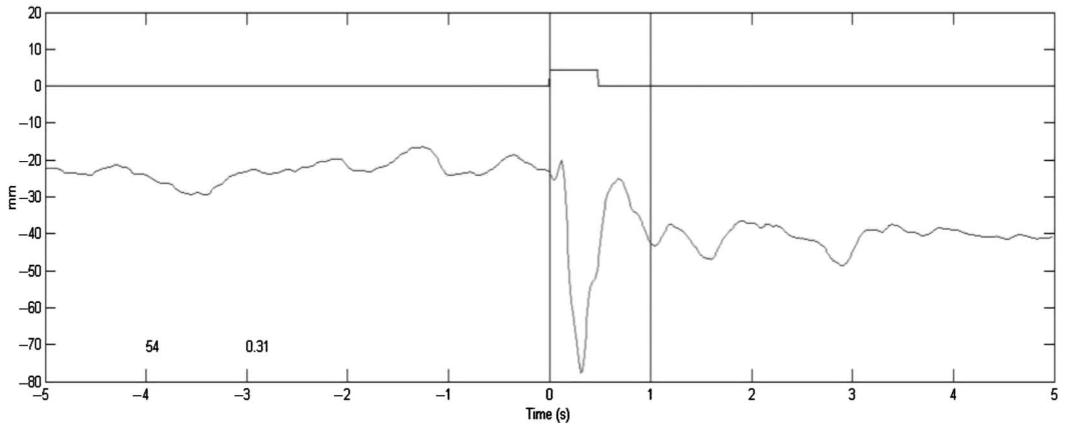

Figure 2. Anterior-posterior position during the perturbation test. A record of the anterior-posterior position of the centre of pressure during the perturbation test. The 2 vertical bars illustrate the 0- to 1-second time window after the sudden perturbation in which the perturbation occurs. The magnitude of displacement is shown vertically (in millimeters) and time is shown horizontally (in seconds).

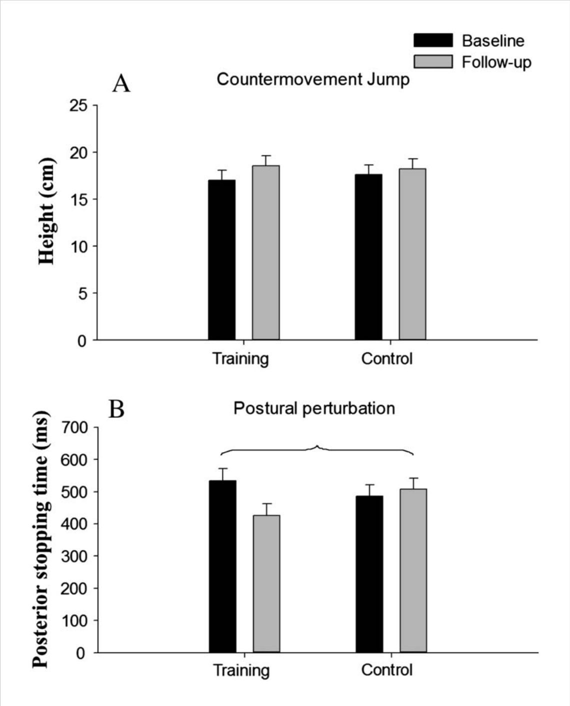

Figure 3. A) Countermovement jump height and B) posterior stopping time after load-release perturbation at baseline and 8-week follow-up in the training and the control group. A significant decrease in posterior movement stopping time after perturbation is shown. Values are mean (*SD*).

participant's CoP. The perturbation was quantified by stopping time in the posterior movement after load drop. The recording ended at 2–3 seconds after the load drop and 3 trials were recorded. During each attempt, the participants had their eyes fixated on a predefined circle (10 cm^2) at eye height, approximately 2 m in front of them.

Countermovement Jump Height. Maximal vertical jump height was assessed in 4 single bilateral countermovement jumps (CMJ) interspersed by 30 seconds rest. The CMJ is characterized by an eccentric pre-stretch phase followed by a propulsive concentric phase characterized by a downward and upward movement of the body center of mass, respectively. The participants were instructed to jump as high as possible with their hands placed on their hips. The jump attempt with the maximum jumping height was selected for statistical analysis.

Training Intervention. The kettlebell training protocol has been described previously (10). In short, training was performed 3 days per week for 8 weeks. Each session lasted 20 minutes and included a 5- to 10-minute warm-up. On completing the warm-up, the participants began 10–15 minutes of interval training. The interval training consisted of 30 s of work followed by 30–60 seconds of rest for 10 bouts, with of 1 of 4 kettlebell exercise progressions ranging from beginner to advanced (Figure 1). During the first 4 weeks, the work-to-rest ratio was 1:2. From week 5, the rest time was reduced to 30 seconds for the remaining training period.

Perceived Changes. At follow-up, the participants replied to a questionnaire on changes they had experienced during the last 8 weeks in terms of muscle strength, wellness, socializing with colleagues, job satisfaction, desire to exercise, physical energy in daily life, and desire to eat healthier on a scale of "decreased," "unchanged," or "increased."

Statistical Analysis

Changes from baseline to follow-up between groups for pre- and post values were determined by analysis of variance using the mixed procedure of the SAS statistical software, version 9.2 (SAS Institute, Cary, NC, USA). Fisher's exact test was used to determine subjective changes in self-perceived characteristics of the pre- and postintervention. Baseline values are reported as mean (*SD*) and changes from baseline to follow-up as mean (95% confidence intervals) unless otherwise stated. A significance level of $p < 0.05$ was considered statistically significant.

Table 2. Between-group differences from baseline to 8-week follow-up on the 2 main parameters.*

	Difference from baseline to 8-wk follow-up		
Outcome measure	Training	Control	Between-group *p* value
Physical tests			
Jump height (cm)	1.5 (0.5 to 2.5)	0.7 (−0.4 to 1.7)	0.24
Stopping time (ms)	−109 (−196 to −21)	21 (−10 to 61)	0.04

*Values are mean (95% confidence interval).

Results

At baseline, the participants in the 2 groups were matched for demographical parameters and physical performance (Table 1). Adherence to training was 70% and 3 participants from each group dropped out of the study. We did not control for time of day testing, nutrition, or hydration levels, but participants were instructed

Table 3. Subjective measures (decreased/unchanged/increased) on self-perceived physical and psychosocial characteristics of the training and control group.*

		Percentage of participants			Fisher's exact test
Outcome	Group	Decreased	Unchanged	Increased	*p* value
Muscle strength	Training	0	21	79	<0.001
	Control	11	84	5	
Wellness	Training	0	47	53	0.01
	Control	5	84	11	
Socializing with colleagues	Training	5	53	42	0.02
	Control	5	89	5	
Job satisfaction	Training	5	74	21	0.046
	Control	0	100	0	
Desire to exercise	Training	0	47	53	0.18
	Control	5	68	26	
Physical energy in daily life	Training	0	68	32	0.23
	Control	5	84	11	
Desire to eat healthier	Training	0	84	16	0.63
	Control	0	89	11	

*Values are percentages of participants.

to not to make any changes in the above during the intervention and for postintervention testing.

The average volume lifted per person per week during the initial (weeks 1–2) and final (weeks 7–8) weeks of training was 184 and 264 kg, respectively, for the 2-handed swing (Figure 1C). For the one-handed kettlebell swing (Figure 1D), the average volume during the initial and final 2 weeks of training was 216 and 180 kg, respectively.

Countermovement Jump Height

Only the training group had a significant improvement in CMJ ($p < 0.01$) from baseline to follow-up, but there was no significant between-group difference (Table 2). Countermovement jumps for each group at baseline and 8-week follow-up is shown in Figure 3A.

Postural Reactions to Perturbation

A record of the AP position of the CoP during the perturbation test is shown in Figure 2. Stopping time in the perturbation test for each group at baseline and 8-week follow-up is shown in Figure 3B. There was a significant between-group difference ($p = 0.04$) from baseline to follow-up with a reduced stopping time of the training group. We observed no improvements in stopping time after load-release perturbation in the control group (Table 2).

Self-Perceived Changes

Significantly more participants in the training vs. control group experienced increased muscle strength ($p < 0.001$), wellness ($p < 0.05$), socializing with colleagues ($p < 0.05$), and job satisfaction ($p < 0.05$) after the 8-week study period (Table 3).

Co-interventions

We registered the participants' level of leisure-time physical activity with a modified version of the Saltin and Grimby (27) questionnaire and no significant difference between groups could be shown. A slight but nonsignificant increase from March to May 2010 was noted in both groups.

DISCUSSION

Our randomized controlled trial shows improvements in postural reactions after perturbation. Furthermore, jump height increased in the training group but was not significantly different from control. This is, to our knowledge, the first randomized controlled trial investigating the effectiveness of kettlebell training for improving postural coordination and jump performance.

Biomechanical factors of kettlebell exercise may explain the positive results on postural coordination and a tendency for improved jump height. The starting position (Figure 1) for the kettlebell swing style in this study is characterized by a stance width of approximately 1.5 times shoulder width with significant ankle dorsi flexion, knee flexion, and hip flexion, aiming for matching torso and shin angle in the sagittal plane. Swinging a kettlebell requires a quick explosive burst of energy mediated by extension of the ankle, knee, and hip at the same time. This fast and synchronized triple extension of the lower limbs propels the kettlebell forward and upward, which then travels by momentum in a coasting phase to the apex of the ascending trajectory. The kettlebell is returned to the starting position by means of eccentric muscle actions that decelerate the kettlebell because it travels down and back between the legs no lower than knee level. The cyclic acceleration-deceleration in the AP plane, observable in kettlebell swings, is visually similar to the acceleration phase or pull phase seen in Olympic weightlifting with only minor differences such as stance width and ankle, knee, and hip flexion in the starting position. We have previously shown significant increases in isometric back extensor strength after 8 weeks of explosive kettlebell swing training (10), which is an indicator of the generation of high peak forces during a kettlebell swing. Additionally, the tendency toward a between-group increase in maximal CMJ and the within-group significant increase reported in this study furthermore point to high peak forces being generated during kettlebell swings.

At the end of the 8-week intervention period, the training group had decreased stopping time moving posterior after perturbation by approximately 20%. A previous training study on back muscle response to sudden trunk loading by Pedersen et al. (22) found a decrease in the amount of trunk flexion (distance covered) because of an approximately 8% improvement in stopping time after 4 weeks of "readiness" training. The readiness training included balance and coordination drills, such as "goalkeeper" exercises with medicine balls and predefined pattern jumping. Similarly, Pedersen et al. (23) found a 13–19% decrease in stopping time in a group of health care workers after 9 weeks of practicing unexpected and expected trunk loading and balance scenarios. The method used in the studies by Pedersen et al. (22,23) has both similarities and differences to the perturbation method in our study. Pedersen et al. (22,23) tested the trunk kinematic response to sudden trunk loading by means of a custom-made loading mechanism wired to a rigid bar and attached to the participant's upper torso while being fixated at hip level. A wire between the load and the subject ran over a reel transforming the gravitational pull on the load to a horizontal load and thereby pulling the torso of the participant forward on load drop. A similar setup has previously been described by Cholewicki et al. (5) with the main difference being a seated position. In our study, the perturbation is occurring by an unloading of the weight from the bar and thereby requiring the participant's posterior and anterior muscles to decrease and increase contractile force, respectively. Furthermore, as the load was released, it caused the whole body to compensate in response to the perturbation, as we did not fixate the participants at hip level. This setup allowed our research team to evaluate whole-body postural coordination in the field and to provide information on whole-body stability. Testing whole-body reactions to outside perturbations provides a more realistic picture on integrated postural coordination efforts in athletic performance and everyday life as most incidents that challenge postural coordination happen on a whole-body level and is not just related to the spine. Compared with the results of Pedersen et al. (22,23,24) who investigated postural reactions to sudden trunk loading following either specific balance and reaction drills or typical soccer drills, a 20% decrease in whole-body stopping time after perturbation is at least noteworthy and raises a few interesting questions. A possible explanation to the improvement in postural coordination observed in this study could be a decrease in muscle activity latency of the trunk extensors as opposed to an increase in trunk flexor strength. We have previously reported highly significant decreases in neck/shoulder pain and low back pain after 8 weeks of ballistic kettlebell training accompanied with significant increases in static back extensor strength of approximately 20% (10), and other research teams have observed significant changes in EMG onset latency after training in patients with low back pain (15,29). This however does not agree with the findings of Pedersen et al. (22) who did not detect any significant changes in EMG onset latency to explain their findings. Pedersen et al. (22) reported that the sampled EMG signal in their study exhibited a minor suppression before the initial burst, which was moved forward in time. It has previously been reported by Mortimer et al. (19) that a silent period before the EMG burst can optimize and increase peak muscular forces. A prepulse inhibition with earlier muscle activity onset as an adaptation of explosive kettlebell training is interesting, and it may help explain the observed changes in postural coordination functioning.

In conclusion, our randomized controlled trial shows a decreased stopping time in posterior movement after perturbation and a tendency toward a between-group increase in jumping height in response to 8 weeks of kettlebell swing training. Together with the previously published data from the same study on increases in static back extensor strength, there is a strong indication that kettlebell swing training improves postural coordination efforts because of the increased strength of the back extensors in untrained individuals.

In a worksite perspective, the primary rationale for implementing exercise programs is increased work engagement and productivity in concert with reduced health care costs (6,11,25). We used a multidimensional approach to promote health, defined as a state of complete physical, social, and mental well-being, where training sessions formed the basis for group cohesiveness through formation of informal groupings. It was hypothesized that group dynamics in the worksite intervention could create exercise compliance, motivation, and overall improve the psychosocial working environment. Multiple factors may contribute to a healthy psychosocial working environment, but according to this study, 8 weeks of kettlebell training can improve job satisfaction, socializing with colleagues, and general wellness (Table 3). These observations could have a direct effect on overall well-being and corporation productivity, whereas long-term effects could be decreased sick leave and employee turnover rate.

Our study has both strengths and limitations. The examiner-blinded, randomized controlled design, the high adherence rate to training, and the small loss of participants to follow-up are noteworthy strengths. In contrast, the relatively small number of participants ($n = 40$) makes it difficult to detect small possible differences between the groups and is therefore a limitation to consider when evaluating the results and recruiting participants for further research.

PRACTICAL APPLICATIONS

Kettlebell training should be considered a novel intervention strategy to possibly reduce common injuries associated with sudden postural perturbations at the worksite and in physical leisure time activities. In this light, kettlebell training can be of high value for fitness professionals to use with their clients. However, contrary to common belief, this study also shows that kettlebell swing training may not be a superior way to develop explosive power as measured by jumping height. Therefore, the recommendation is to consider conventional exercise alternatives when lower-body explosive power and increases in jumping height are the training goals.

Finally, group-based kettlebell training deliver benefits such as increased overall well-being, job satisfaction, and self-reported muscular strength that are valuable psychosocial factors and should be considered an alternative to more common strategies.

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