International Journal of EXERCISE SCIENCE

Original Research

Effects of Six-week Periodized Versus Non-Periodized Kettlebell Swing Training on Strength, Power and Muscular Endurance

EVALDO RUI TAVARES SANTOS JUNIOR†[1,2], BELMIRO FREITAS DE SALLES‡[2], INGRID DIAS‡[1,2], ROBERTO SIMÃO‡[1,2], and JEFFREY M. WILLARDSON‡[3]

[1]Physical Education Post-Graduation Program, UFRJ, Rio de Janeiro, Brazil; [2]Strength Training Lab Brazil (STLAB), Rio de Janeiro, Brazil; [3]Health and Human Performance Department, Montana State University Billings, Billings, MT, USA

†Denotes graduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 15(4): 526-540, 2022. The purpose of this study was to compare a periodized versus a non- periodized protocol of kettlebell (KTB) swings over six weeks on strength, power, and muscular endurance. Twenty-eight high intensity functional training (HIFT) practitioners were assigned to non-periodized (NPG = 11), periodized (PG = 11), or control groups (CG = 6). NPG used the same load (20 kg) throughout the training period while the PG used a step loading progression (with an added four kilograms every two weeks). Measures of strength and muscular endurance in the deadlift exercise, and power in the countermovement jump were assessed before and after six weeks. A two-way ANOVA was used to verify pre- to post-test differences in strength, power, and muscular endurance. An analysis of the effect size was also incorporated. For strength and power, statistical differences from pre- to post-test were found for both the NPG ($p < 0.001$; 1-RM improvement = 8.7%; jump height improvement = 8.7%) and PG ($p < 0.001$; 1-RM improvement = 7.8%; jump height improvement = 10.1%), with no difference between groups. For muscular endurance, only the PG showed significant differences from pre- to post-test ($p = 0.013$; muscular endurance improvement = 23.8%). In conclusion, when the goal is to increase strength and power performances in HIFT practitioners, periodized and non-periodized KTB models appear to be equally effective, and this can simplify the strength coach's practice in programming KTB swing training periods. For muscular endurance, the addition of KTB swing on a periodized basis seems to be a more effective strategy.

KEY WORDS: Kettlebell swing, periodization, strength, power, muscular endurance, HIFT

INTRODUCTION

Periodization is commonly defined as a logical method of organizing training in sequential phases to reduce the risk of injury and optimize performance through manipulation of training loads (10, 16, 38). For intermediate and advanced practitioners, the American College of Sports Medicine (ACSM) recommends a variation in volume and load intensity (from 1 to 12 RM) in a periodized fashion (24). The ACSM's recommendations are corroborated by meta-analysis that compared periodized to non-periodized resistance training programs and showed that periodized programs were more effective for strength (25, 38) and power gains (25).

One of the important aspects of periodization is the organization of training loads, which is related to how the loads will progress in each period (3). The main ways to progress in training loads are through linear, step and undulatory organizations (3, 36). The undulatory progressions consist of making a wave-like progressive increases in load intensity over a period. Linear progressions are characterized by progressive and gradual increases in load intensity, whereas step progressions have a stabilization in the load intensity whenever a progression is made (which favors the adaptation before a new increase in the load intensity is made). The efficacy and fundamentals of linear and step progressions lead us back to ancient Greece (6th century B.C.), where the famous Olympian wrestler Milo of Croton was able to carry a bull around a stadium. His training strategy was to lift a bull-calf daily until it was fully grown, which caused his strength to increase progressively (1, 33). The principle of progressive overload exemplified by Milo can now be applied to several means of resistance training, such as barbells, dumbells and kettlebells (KTB).

KTB is an alternative resistance training approach to strength and power development whose use has grown over the years (5, 9). The KTB is a cast iron ball whose shape allows its center of mass to extend beyond the hand, which allows the accomplishment of bilateral and unilateral exercises in all planes (17). While some KTB exercises such as overhead press are also used with other resistance training implements like barbell and dumbbell, other exercises are more appropriate when performed with KTB (11), one of which is the swing. The swing is a central exercise in KTB training, which involves predominantly flexion in the hip joint and to a lesser extent in the knee and ankle joints, and a subsequent explosive extension of the hips to swing the KTB up to approximately chest level where the hips and knees are completely extended and the subject is standing upright (40) (Figure 1). Previous investigations that used the kettlebell swing as a training method found increases in strength and power ranging from 4.5% to 12.03% in back squat and from 2.17% to 15% in vertical jump height (15, 21). However, it is not yet known whether performing KTB training in a periodized fashion is better than KTB training in a non-periodized program. Answering this question will bring important information related to the progression of loads in KTB training, and therefore possibly will collaborate in the optimization of results when using this resistance training tool, for example in high intensity functional training (HIFT) programs. HIFT comprises a combination of elevated intensity functional movements, which primarily uses multi-joint exercises such as Olympic weightlifting exercises, body-weight exercises, and aerobic training (34). Investigating the effect of KTB training on strength, power, and muscular endurance gains in HIFT practitioners is important because these biomotor abilities are demanded in many HIFT modalities. Thus, it is expected that the present study can provide evidence to assist strength coaches and personal trainers in prescription of kettlebell training programs for greater power, strength and muscular endurance gains.

In this sense, the purpose of this study was to compare a periodized versus a non-periodized protocol of KTB swings over six weeks on strength, power, and muscular endurance. It was hypothesized that the non-periodized protocol would be less effective versus the periodized protocol. The initial hypothesis was based on the idea that long periods without variation in training loads can result in fatigue and stagnation in training adaptations (12, 39). Therefore, as the individual adapts to the training stimulus, an increase in stress must be provided to allow the optimization of adaptations (8). The principle of progressive overload, which will generate an increase in training stress, can be achieved in three ways (8): by increasing the training session volume (number of sets or repetitions); an increase in weekly frequency of exercises; or by increasing the load intensity for a training volume. In the present study, the progression of the training load occurred by increasing the load intensity, providing a greater variation in training stimuli, which may lead to greater adaptations.

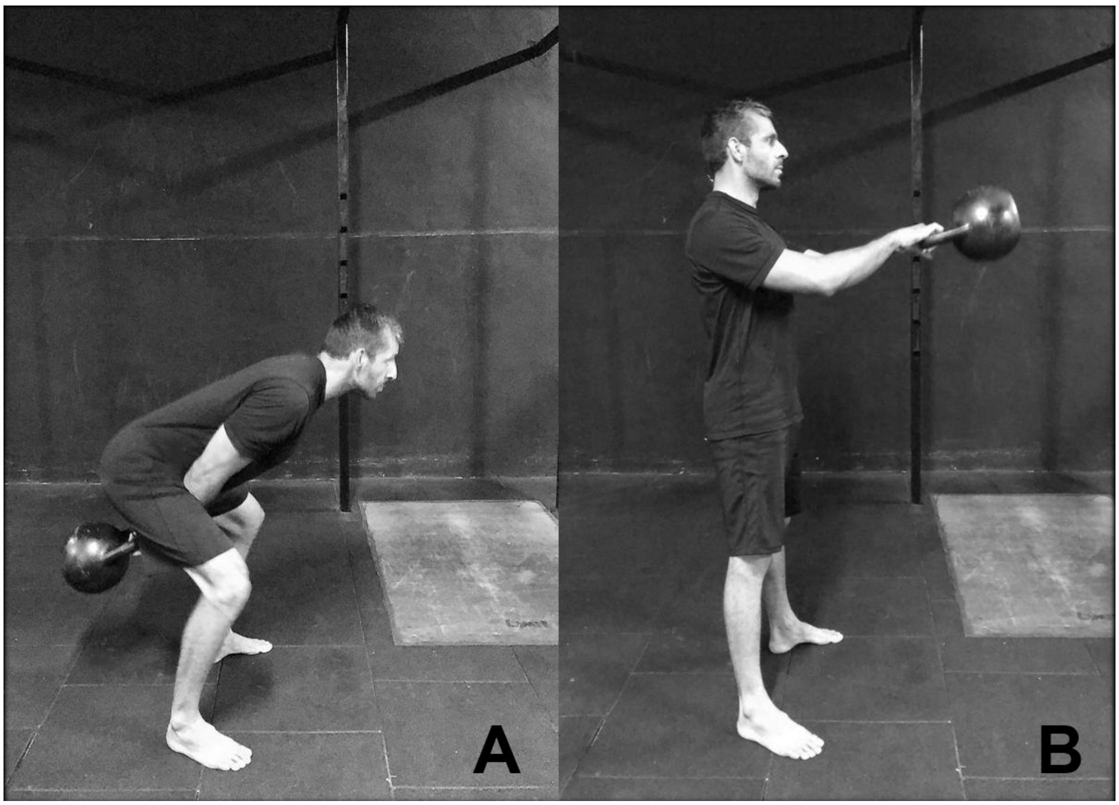

Figure 1. Start (A) and finish (B) position of the kettlebell swing.

METHODS

Participants

A convenience sample of twenty-eight men (29.3 ± 7.5 years; 176.1 ± 6.3 cm; 78.8 ± 10.7 kg; 143.1 ± 23.0 kg in deadlift 1RM; 1.82 ± 0.24 kg/body mass deadlift relative strength); 2.1 ± 1.3 years of training experience), with at least six months of experience with HIFT exercises (including KTB training) participated in this study. No differences ($p \geq 0.05$) were observed before training in age, height, body mass, deadlift 1RM, deadlift relative strength and training experience between groups (see Table 1). The following inclusion criteria were adopted: a) having at least six months of experience in KTB training; b) between 18 and 50 years old; c) practice HIFT for at least six months, at least three times a week (with one-hour sessions), performing at least four exercises per session, and at least three sets per exercise. Additionally, the following health related exclusion criteria were adopted: a) having answered "yes" to one of the PAR-Q questionnaire items (29); b) having any functional limitation or injury that could be made worse by performance of the experimental testing or training sessions. This research was carried out fully in accordance to the ethical standards of the international Journal of Exercise Science (20). The study was approved by the Ethics Committee of the Federal University of Rio de Janeiro, and all subjects were volunteers and gave their written informed consent.

Table 1. Baseline characteristics (mean ± SD).

Groups	Age (y)	Height (cm)	Body mass (kg)	Deadlift 1RM (kg)	Relative Strength	Training experience (y)
NPG (*n* = 11)	29.2 ± 8.3	175.2 ± 6.2	78.9 ± 11.5	149.5 ± 23.3	1.9 ± 0.2	2.4 ± 1.2
PG (*n* = 11)	29.3 ± 6.5	176.9 ± 7.0	78.4 ± 9.5	137.7 ± 27.5	1.7 ± 0.1	2.0 ± 1.6
CG (*n* = 6)	29.6 ± 9.4	176.1 ± 6.2	79.6 ± 13.2	141.3 ± 10.4	1.8 ± 0.3	1.75 ± 1.0

NPG = non-periodized group; PG = periodized group; CG = control group.

Protocol

The training protocol used was an adaptation of a program called *minimum* (35), whose format has already been used in previous studies (4, 15, 23). The protocol was performed twice a week (on non-consecutive days), and consisted of performing 12 sets of thirty seconds of KTB swing, alternating with thirty seconds of rest (see Figure 2). Subjects were instructed to perform the maximum number of repetitions in each set, and, under the certified KTB instructor supervision, the exercise was performed according to the guidelines recommended by Tsatsouline in Enter the Kettlebell (35). The subjects received following instructions: 1) keep your back straight; 2) project your hips backward, not downward; 3) focus on powerful hip extension, not arm movement; 4) fully extend your hips and knees, with the body forming a straight line at the end of the movement; 5) at the top of the movement, the KTB should be an extension of your arms.
To examine the differences between groups, measures of strength and muscular endurance in the deadlift exercise and power in the countermovement jump (CMJ) were obtained one week before and one week after the six-week period. The non-periodized group (NPG) performed the training protocol with the same intensity throughout the training period (20 kg); the periodized group (PG) used a step loading progression (36) with four-kilogram progression every two weeks (starting at 16 kg for two weeks, 20 kg for two more weeks and 24 kg for the next two weeks) (see Figure 3). Training loads were organized in this way so that the average training intensity (the sum of the load intensities in each session divided by the number of sessions) was the same, aiming that the volume load realized by the experimental groups remained equalized. During the intervention period, all subjects continued to perform the HIFT program (including the control group).

Muscle power was measured by the CMJ test. Initially, the subjects performed three sets of ten repetitions of a general warm-up consisting of the hip hinge exercise with a stick and the ground to overhead exercise with a 10 kg plate. Then, subjects performed a CMJ with the hands on the hips. Two jumps were performed with a five-minute rest interval between attempts, and the highest one was recorded. The app used to calculate the jump height was *My Jump 2* (Apple Inc., USA). To register the CMJ, the researcher lay with his body down at 1.5 meters from the individual, with the iPhone 6 facing the subject in the frontal plane. The take-off phase was obtained in the first frame where both feet were off the ground, and the landing phase was considered the first frame in which at least one foot was touched the ground (2). The app calculated the jump height (reported in centimeters) from flight time. The literature shows high reliability between the *My Jump 2* and the force platform CMJ jump heights (ICC = 0.997, 95% CI: 0.996–0.998, $P < 0.001$), almost perfect correlation ($r = 0.995$, $P < 0.001$), and very good reliability for five CMJ measured by two independent observers with no prior experience on video analysis (observer 1: $\alpha = 0.997$, CV = 3.4%; observer 2: $\alpha = 0.988$, CV = 3.6%) (2).

Maximum strength was measured by the 1RM test in deadlift exercise. Approximately ten minutes after performing the CMJ test, individuals performed a warm-up with three sets of submaximal repetitions with progressive loads (five reps at 50%, four reps at 60%, and three reps at 70% of 1RM). Subjects received the following instructions: 1) keep your back straight; 2) keep the bar close to you throughout the movement; 3) fully extend your hips and knees, with the body forming a straight line at the end of the movement; 4) return with the bar without releasing it on the floor.

To find the maximum load for one repetition, everyone had up to four trials with rest periods of three to five minutes between trials (verbal encouragement was provided during all 1RM attempts). Resistance was progressively increased until the individuals could not complete the selected repetition, and the final weight lifted successfully was considered the absolute 1RM (27). For a repetition to be considered valid, subjects had to finish the concentric phase with the knees and hips extended, trunk erect, and shoulder girdle retracted. (6). For standardization purposes, the conventional deadlift style was adopted. Individuals were instructed to use the grip they preferred.

Approximately ten minutes after the 1RM test, muscle endurance was assessed by a 50% 1RM conventional deadlift test, in which subjects were instructed to perform as many repetitions as possible with the appropriate technique (9, 28). The individuals were instructed to complete each repetition with the knees and hips fully extended, trunk erect, and shoulder girdle retracted (6). Additionally, the plates had to touch the ground before a new repetition began. For standardization purposes, only the double overhand grip (palms facing backward) was allowed.

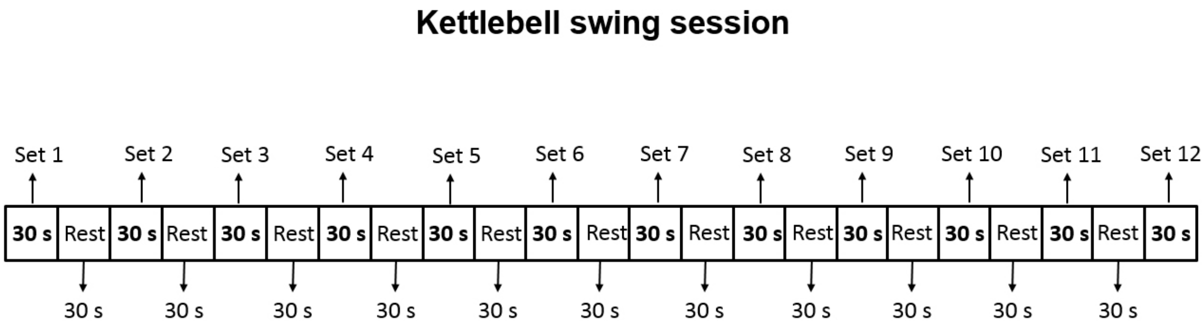

Figure 2. Kettlebell swing session.

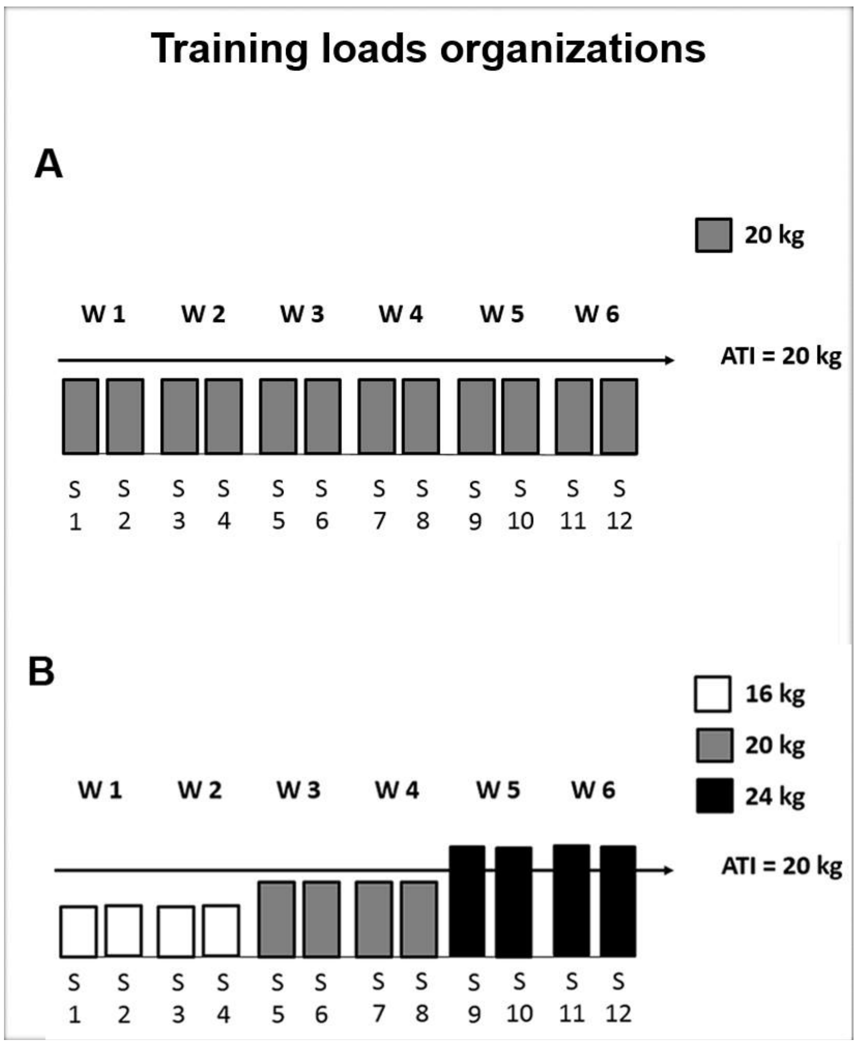

Figure 3. NPG load organization over six weeks (A). PG load organization over six weeks (B). W = week; S = session; ATI = average training intensity.

Statistical Analysis

A 3 (group) x 2 (test) repeated measures analysis of variance (ANOVA) was used to verify pre- to post-test differences in maximum strength, power, and muscular endurance. A *t*-test for independent samples was used to verify differences in repetitions per session, the total number of repetitions, and the volume load (total number of repetitions x average training intensity) between experimental protocols. A paired *t*-test was used to compare the number of repetitions performed by the experimental groups in the first week with the number of repetitions in the sixth week. A repeated measures ANOVA were used to compare the number of repetitions performed by the PG with the different KTB load intensities (16 kg x 20 kg x 24 kg). Effect size (ES) was calculated as the change score divided by the standard deviation of the change score (7). All statistical analyses were performed with SPSS v.20.0 (IBM Corp., Armonk, NY, USA), and the statistical significance was set at $p < 0.05$, *a priori*.

RESULTS

There were no differences (t (20) = 0.51; p = 0.61) in repetitions per session, total number of repetitions, volume load between NPG and PG, and the number of repetitions performed between the first and last week for NPG (t (10) = -0.86; p = 0.40) and PG (t (10) = -0.15; p = 0.88) (see Table 2). There was also no difference in the number of repetitions performed by the PG with different KTB load intensities (F (2, 20) = 0.731; p = 0.49). Repeated measures analysis for maximum strength revealed a significant pre- to post-test differences (F (1, 25) = 38.787; $p <$ 0.001) for NPG ($p <$ 0.001) and PG ($p <$ 0.001), but there was no statistical difference between groups (F (2, 25) = 1.712; p = 0.201) (see Figure 4). Repeated measures analysis for jump height also revealed a statistical pre- to post-test differences (F (1, 25) = 14.071; p = 0.001) for NPG (p = 0.003) and PG (p = 0.001), but with no statistical difference between groups (F (2, 25) = 12.645; p = 0.091) (see Figure 5). For muscular endurance, repeated measures analysis revealed significant pre- to post-test differences (F (1, 25) = 0.454; p = 0.045), indicating a significant performance increase for PG only (p = 0.013) (see Figure 6). For maximum strength, the ES was large for NPG and PG and moderate for CG. For jump height, ES was large for the experimental groups and trivial for CG. For muscular endurance, ES was large for PG, small for NPG and trivial for CG (see Table 3).

Table 2. Repetitions per session, total number of repetitions and volume load (mean ± SD).

Groups	Repetitions per session	Total number of repetitions	Volume load	Repetitions in week 1	Repetitions in week 6
NPG (n = 11)	251.7 ± 8.4	3021.3 ± 101.3	60427.2 ± 2027.0	506.2 ± 35.3	519.5 ± 39.0
PG (n = 11)	249.4 ± 12.0	2994.0 ± 145.0	59880.0 ± 2901.0	503.5 ± 30.8	505.0 ± 33.2

NPG = non-periodized group; PG = periodized group.

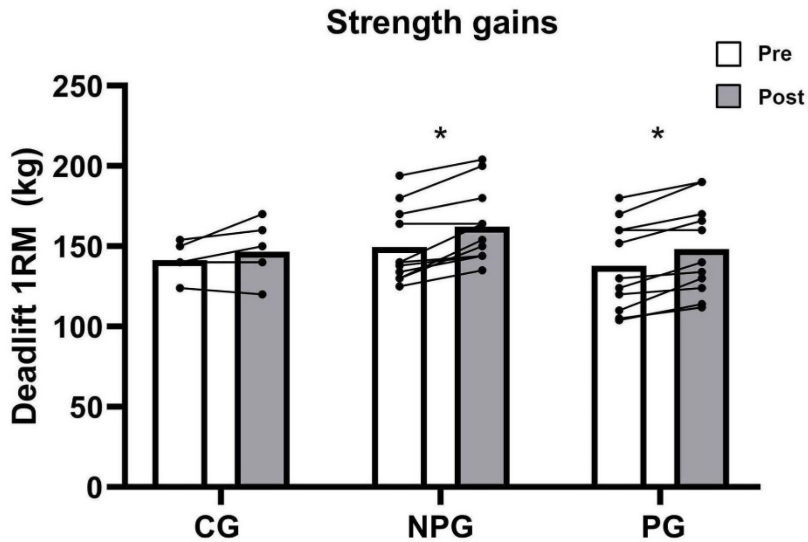

Figure 4. Deadlift 1RM pre- and post-training for the non-periodized (NPG), periodized (PG) and control (CG) groups. *Significant difference from pre- to post-training.

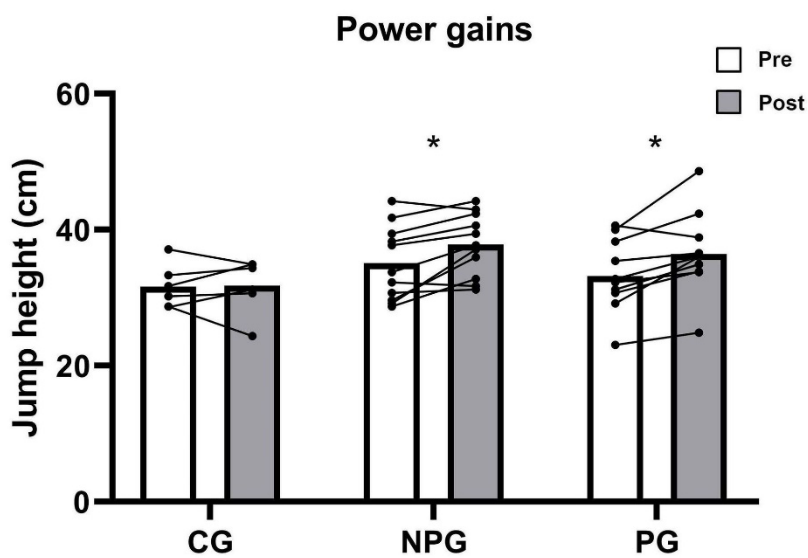

Figure 5. Jump height pre- and post-training for the non-periodized (NPG), periodized (PG) and control (CG) groups. *Significant difference from pre- to post-training.

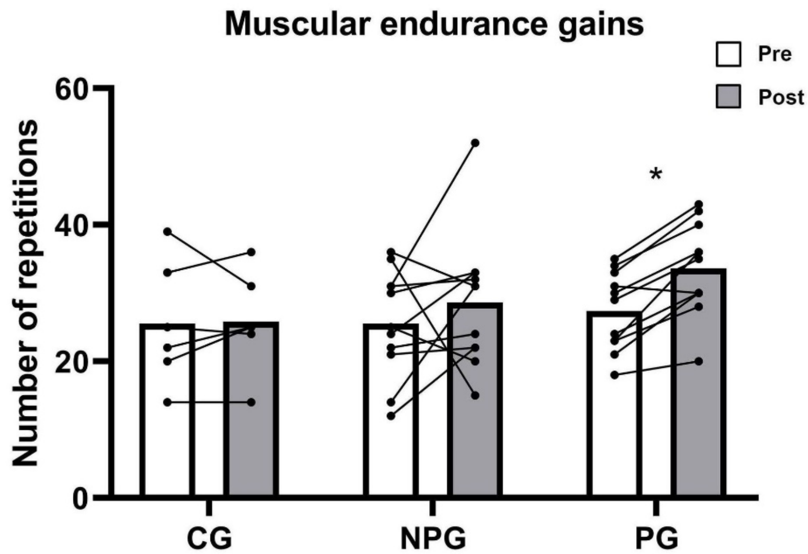

Figure 6. Deadlift muscular endurance pre- and post-training for the non-periodized (NPG), periodized (PG) and control (CG) groups. *Significant difference from pre- to post-training.

Table 3. Pre- and post-training measures, effect sizes, magnitudes, and percentage change pre- to post-training.

Variable	Groups	Pre	Post	ES	ES Magnitude	Δ% (95% CI)
	NPG	149.5 ± 23.3	162.0 ± 23.3	1.52	Large	8.7% (4.6 to 12.7)
Deadlift 1-RM	PG	137.7 ± 27.5	148.1 ± 28.4	1.59	Large	7.8% (4.4 to 11.3)
	CG	141.3 ± 10.4	146.6 ± 17.5	0.61	Moderate	3.5% (-2.7 to 9.8)
	NPG	35.0 ± 5.4	37.8 ± 4.5	1.00	Large	8.7% (2.4 to 14.9)
Jump height	PG	33.1 ± 5.1	36.4 ± 5.8	1.18	Large	10.1% (4.8 to 15.3)
	CG	31.6 ± 3.2	31.7 ± 4	0.04	Trivial	0.4% (-9.5 to 10.4)
	NPG	25.5 ± 7.9	28.6 ± 9.8	0.27	Small	22.3% (-12 to 56.7)
Muscle endurance test	PG	27.3 ± 5.7	33.6 ± 6.8	1.69	Large	23.8% (13.4 to 34.2)
	CG	25.5 ± 9.0	25.8 ± 7.4	0.07	Trivial	1.3% (-20.6 to 23.2)

NPG = non-periodized group; PG = periodized group; CG = control group. ES = effect size; Δ% = percentage change.

DISCUSSION

The purpose of this study was to compare a periodized versus a non-periodized model of KTB swing over six weeks on strength, power, and muscular endurance. The main findings were: 1) both protocols showed significant increases in deadlift 1RM and jump height after six weeks, without significant difference between them; 2) Only the periodized protocol resulted in significant increases in deadlift muscular endurance after six weeks.

The results of this study agreed with three studies that investigated the effect of biweekly KTB training on jump height and lower limb strength (15, 18, 21). Lake and Lauder (15) compared a jump squat program versus a KTB swing program (KSP). The KSP consisted of performing the same protocol as the present study, however the load intensities were fixed (men with a body mass < 70 kg used a 12-kg KTB, whereas men with a body mass > 70 kg used a 16-kg KTB). After six weeks, both groups increased the jump height and the back squat 1RM performances, with no difference between groups. In this study, the percentage pre- and post-training differences for jump height in the KSP (15%) was apparently higher than the NPG (8.7%) and the PG (10.1%) in the present study. A possible explanation for these findings is the fact that the individuals in the study by Lake and Lauder probably had less training experience than the individuals in the present study (a minimum of three months versus a minimum of six months, respectively), considering that individuals with higher training levels may show less responsiveness to training. This can be confirmed by analyzing the pre-training mean in the jump height performance between the participants in the aforementioned studies (20 cm x 33.5 cm).

Otto et al. (21) also investigated the effect of six weeks of KTB training but compared it with a weightlifting program. The KTB training program consisted of three weeks of 3 x 6 (KTB swings), 4 x 4 (accelerated swings), and 4 x 6 (goblet squats); and three more weeks of 4 x 6 (KTB swings), 6 x 4 (accelerated swings), and 4 x 6 (goblet squats), always using a 16-kg KTB. The results showed a 2.17% improvement in jump height performance and a 4.5% in back squat 1RM. These results were lower than those found in the present study (10.1% in jump height performance and 7.8% in deadlift 1RM for PG), and the difference in the number of repetitions performed in each study may explain this discrepancy. This same explanation (in addition to the shorter duration of the intervention) can be used to explain the difference between the results of the present study and the study by Maulit et al. (18), which compared the effect of a swing protocol versus an explosive deadlift protocol on the jump height and maximum strength. This study lasted only four weeks and maximum strength was measured in the deadlift exercise, as in the present study. The load intensity in the KTB protocol was 10% peak delta force from the isometric mid-thigh pull for two weeks (4 sets of 5 reps), and 12.5% (6 sets of 4 reps) in the other two weeks. KTB protocol significantly improved the strength (approximately 5%) and the jump height performance (approximately 2%).

It is not feasible to compare the variation in training loads on strength and power gains with other KTB training studies since, to the best of our knowledge, no study has investigated this outcome. Comparing with traditional resistance training studies, the results of the present study apparently differ from others found in the literature. Stone et al. (31) compared three different resistance training programs, two of which were periodized and one was not. The non-periodized predominantly used 5 x 6 RM in the major exercises (Squat, Bench press, Clean pull, and Power shrug) and 3 x 8 RM in the assistance exercises (Incline press and Lat pull downs), and the periodized programs used a varied volume and intensity scheme (reducing the number of repetitions over 12 weeks). After 12 weeks, only periodized programs showed differences in 1RM gains in the squat. Based on these results, the authors suggested that the appropriate sequence and manipulation of training variables were important in obtaining results, not just the training volume performed. However, an important aspect in the study by Stone et al. (31) was the fact that the periodized programs at the end of the intervention performed a volume of repetitions closer to that of the 1RM test, in this case the specificity (and not the variation) would explain the results. This reasoning does not apply to the present study because, although the PG used greater intensities than the NPG at the end of the intervention, there were no significant differences in strength gains between groups. A possible explanation for this result is the fact that, although not statistically significant, the NPG performed a greater training volume, which may have contributed to the lack of difference in the results between the experimental groups. In addition, despite the swing and deadlift showing similarities from a biomechanical perspective (considering the angular displacement of the hip, knee, and ankle joints over the entire range of motion), the absolute intensities used in the former are substantially lower than those of the latter. In this sense, the relevance of KTB swing in increasing strength lies in challenging time-limited force expression and differentially challenging motor demands, and not by using high intensities per se (32).

Monteiro et al. (19) also compared three resistance training programs with equalized training volumes (one non-periodized and two periodized) on strength gains. One of the periodized models was called linear (with a progressive increase of loads) and the other nonlinear (with greater variation of loads). After 12 weeks, the results showed that the most effective model was the nonlinear (with strength gains observed at 4, 8, and 12 weeks for both the bench press and leg press), followed by the linear model (with strength gains occurring only in week 8 in leg press). The non- periodized model showed no differences in strength increase for both exercises. Another study (30) also compared a non- periodized model with the linear (called traditional) and nonlinear (called undulatory) periodized models. Differing from both the aforementioned studies and the present study, the authors found differences for the non-periodized model and the undulatory model in squat strength gains after 6 weeks (no significant differences were found for linear periodized model). A possible explanation given by the authors was based on specificity, since the linear group concentrated a longer period with low intensity and high volume than the other two groups. This kind of specificity may not explain the results of the present study, since KTB swing is a predominantly ballistic exercise whose intensities are quite different from those used in the deadlift 1RM tests.

Some studies compared periodized versus non- periodized resistance training programs on power gains. O'Bryant et al. (21) divided ninety college males into periodized (using a progressive load regime, starting with high volume and low intensity, and progressing to low volume and high intensity) and non-periodized group (using a 3 x 6 RM). The exercises used were: Parallel squat, Bench press, Hyperextensions, and Sit-ups (Monday and Friday), and Clean pulls (floor), Clean pull (mid-thigh), Shoulder shrugs, Behind the neck press, and Sit-ups (Wednesday). After evaluating power capacity by incremental cycle ergometer exercise, the authors found that after 11 weeks the periodized group presented better results than the non-periodized group.

Similarly, Kraemer et al. (14) compared the physiological and performance adaptations between periodized and non- periodized resistance training in thirty women collegiate tennis athletes. The same exercises were used for both groups and were basically repeated on Mondays, Wednesdays, and Fridays (Leg press, Bench press, Unilateral leg curl, Shoulder press, Seated cable row, Calf raise, Latissimus pull down, Dumbbell lateral raise, Lumbar extension, Dumbbell internal rotation, Dumbbell external, Abdominal crunch). The periodized group performed 2-3 sets of 4-6RM on Monday, 8-10RM on Wednesday, and 12-15RM on Friday, while the non- periodized group performed 2-3 sets of 8-10RM throughout the study period. After nine months, the periodized group resulted in significantly greater improvements in jump height compared to the non- periodized group (50 ± 9% vs 37 ± 7%). These results occurred despite similar training volumes, leading the authors to speculate the importance of including variation as a relevant factor in a training program. An important difference between the study by Kraemer and colleagues and the present study was the intervention time (nine months vs six weeks). Throughout the study, measurements were taken in the fourth, sixth and ninth months, and the analysis of the Δ% for jump height only showed a statistical difference between the periodized and the non-periodized group in the measure of the ninth month, and that may partly explain the difference in results between studies.

Some hypotheses may explain the conflicting findings between the present study and the studies presented regarding strength and power gains. The first is the fact that possibly the volume load would be more important than variation when KTB swing is used for strength and power gains. In this case, the amount of mechanical work performed would be the determining factor for improving performance, at least for a six-week period. Still on the training volume hypothesis, it is important to note that, although not statistically significant, the NPG performed a greater number of repetitions than the PG, which may have impacted the results, compensating for the lack of variation in training loads by the greater number of total repetitions performed. In addition, the NPG showed an increase in the number of repetitions from the first to the sixth week and, although it was also not statistically significant, this unplanned progression may have influenced the strength and power gains.

The second and perhaps more plausible hypothesis would be the short intervention time of present study compared to the forementioned studies. Considering the tendency of the organism to adapt to a training stimulus, the planned variation would contribute to avoid plateau and maintain stimulus effectively, especially in longer training periods. The third explanation, especially for strength gains, is the specificity hypothesis. Considering the intensity, KTB training is less specific than traditional resistance training, but its contribution is still relevant to strength gains by challenging time-limited force expression (32). For this purpose, the variation in intensities does not seem to be important. Furthermore, increased trunk and hamstrings muscles strength provided by KTB swing can also contribute to improvements in strength exercises (15).

To our knowledge, no prior studies have examined the effect of a KTB swing protocol on muscular endurance measured by a multi-joint resistance training exercise, so making comparisons with other studies is not feasible. Likewise, comparing the findings of the variation in training loads on muscular endurance with other studies in the literature are difficult to establish since no studies investigating periodized with non- periodized programs have been identified. However, considering the recommendation to progress from general to specific (13, 37), the most appropriate load organization to be applied to improve muscular endurance would be to increase volume and reduce the intensity (reverse linear organization). Rhea et al. (26) compared the reverse linear, daily undulatory and linear load organizations and, although no significant differences were observed between groups (RLP = 73%, LP = 56%, DUP = 55%; *p* =

0.58), analysis of the effect size demonstrated that the reverse linear was more effective than daily undulatory and linear load organizations to increase muscular endurance. In the present study, specifically for the PG, the pattern of load intensity was the opposite of the reverse linear, yet the PG showed the best results for the muscular endurance variable. A possible explanation for these results would be the fact that greater variations in training loads are more effective for muscular endurance gains. Another explanation is found in the submaximal nature of the KTB swing, which allowed the same volume of repetitions to be performed between higher load intensities (24-kg KTB) compared to lower load intensities (16-kg KTB). Despite performing the same volume load, at the end of the experimental period the PG performed the swing protocol with an intensity greater than the NPG (24 kg x 20 kg, respectively), possibly allowing individuals in the PG to be more adapted to tolerate greater discomfort in the muscular endurance test, which could potentially generate better performance. Despite having produced a high percentage increases, the non- periodized protocol did not present statistically significant post-intervention improvements, suggesting that there is no difference in adding a non-periodized KTB swing protocol for HIFT practitioners when the goal is to improve muscle endurance. However, the largest standard deviation in the data of this group can explain these results, as this increases the chances of type 2 error.

This study had some limitations such as the sample size of the control group (smaller than the experimental groups), the short intervention period, and the fact that the subjects' diet was not controlled, decreasing the internal validity of the study. Future studies may investigate other populations (including women), longer intervention periods, and other load organizations (e.g., undulatory progression).

In conclusion, the addition of KTB swing with a planed variation in training loads seems to be the most appropriate strategy to achieve the best results when the goal is to increase muscular endurance in HIFT practitioners, considering the statistically significant post-intervention improvements, and the higher magnitude of the ES. For strength and power improvements, it appears that there is no difference between a varied and a non-varied model when the volume load is equalized (at least in the six-week period), as both periodized and non- periodized models were equally effective in generating 1RM deadlift and jump height improvements, and this can simplify the strength coach's practice in programming KTB swing training periods. Therefore, strength coaches should consider including KTB training protocols in HIFT training routines for optimization of neuromuscular adaptations.

REFERENCES

1. Abe T, Loenneke JP, Fahs CA, Rossow LM, Thiebaud RS, Bemben MG. Exercise intensity and muscle hypertrophy in blood flow-restricted limbs and non-restricted muscles: a brief review. Clin Physiol Funct Imaging 32: 247-252, 2012.

2. Balsalobre-Fernández C, Glaister M, Lockey RA. The validity and reliability of an iPhone app for measuring vertical jump performance. J Sports Sci 33: 1574-9, 2015.

3. Bompa TO, Buzzichelli CA. Periodization: Theory and methodology of training. 6th ed. Champaign, IL: Human Kinetics, 2018.

4. Budnar Jr RB, Duplanty AA, Hill DH, McFarlin BK, Vingren JL. The acute hormonal response to the kettlebell swing exercise. J Strength Cond Res 28: 2793-800, 2014.

5. Bullock G, Schmitt A, Shutt J, Cook G, Butler R. Kinematic and kinetic variables differ between kettlebell swing styles. Int J Sports Phys Ther 12: 324-32, 2017.

6. Camara KD, Coburn JW, Dunnick DD, Brown LE, Galpin AJ, Costa PB. An examination of muscle activation and power characteristics while performing the deadlift exercise with straight and hexagonal barbells. J Strength Cond Res 30: 1183-8, 2016.

7. Dankel SJ, Loenneke JP. Effect sizes for paired data should use the change score variability rather than the pre-test variability. J Strength Cond Res 36: 1773-1778, 2021.

8. Dankel SJ, Mattocks KT, Jessee MB, Buckner SL, Mouser JG, Counts BR, Laurentino GC, Loenneke JP. Frequency: The overlooked resistance training variable for inducing muscle hypertrophy?. Sports Med 47: 799-805, 2017.

9. de Lima C, Boullosa DA, Frollini AB, Donatto FF, Leite RD, Gonelli PR, Montebello MI, Prestes J, Cesar MC. Linear and daily undulating resistance training periodizations have differential beneficial effects in young sedentary women. Int J Sports Med 33: 723-727, 2012.

10. DeWeese BH, Hornsby G, Stone M, Stone MH. The training process: planning for strength–power training in track and field. Part 1: theoretical aspects. J. Sport Health Sci 4: 308–317, 2015.

11. Dicus JR, Holmstrup ME, Shuler KT, Rice TT, Raybuck SD, Siddons CA. Stability of resistance training implement alters emg activity during the overhead press. Int J Exerc Sci 11: 708-716, 2018.

12. Evans JW. Periodized resistance training for enhancing skeletal muscle hypertrophy and strength: A mini-review. Front Physiol 10: 1-7, 2019.

13. Issurin VB. New horizons for the methodology and physiology of training periodization. Sports Med 40: 189-206, 2010.

14. Kraemer WJ, Hakkinen K, Triplett-Mcbride NT, Fry AC, Koziris LP, Ratamess NA, Bauer JE, Volek JS, McConnell T, Newton RU, Gordon SE, Cummings D, Hauth J, Pullo F, Lynch JM, Fleck SJ, Mazzetti SA, Knuttgen HG. Physiological changes with periodized resistance training in women tennis players. Med Sci Sports Exerc 35: 157-68, 2003.

15. Lake J, Lauder M. Kettlebell swing training improves maximal and explosive strength. J Strength Cond Res 26: 2228-33, 2012.

16. Lorenz DS, Reiman MP, Walker JC. Periodization: current review and suggested implementation for athletic rehabilitation. Sports Health 2: 509-18, 2010.

17. Manocchia P, Spierer D, Lufkin AK, Minichiello J, Castro J. Transference of kettlebell training to strength, power, and endurance. J Strength Cond Res 27: 477-84, 2013.

18. Maulit MR, Archer DC, Leyva WD, Munger CN, Wong MA, Brown LE, Coburn JW, Galpin AJ. Effects of kettlebell swing vs. explosive deadlift training on strength and power. Int J Kinesiol Sports Sci 5: 1-7, 2017.

19. Monteiro AG, Aoki MS, Evangelista AL, Alveno DA, Monteiro GA, Piçarro Ida C, Ugrinowitsch C. Nonlinear periodization maximizes strength gains in split resistance training routines. J Strength Cond Res 23: 1321-6, 2009.

20. Navalta JW, Stone WJ, Lyons TS. Ethical issues relating to scientific discovery in exercise science. Int J Exerc Sci. 2020 Sep 1;12(1):1-8. PMID: 33042361; PMCID: PMC7523901.

21. O'Bryant HS, Byrd R, Stone MH. Cycle ergometer performance and maximum leg and hip strength adaptations to two different methods of weight-training. J Strength Cond Res 2: 27-30, 1988.

22. Otto W, Coburn J, Brown L, Spiering B. Effects of weightlifting vs. kettlebell training on vertical jump, strength, and body composition. J Strength Cond Res 26: 1199-202, 2012.

23. Raymond LM, Renshaw D, Duncan MJ. Acute hormonal response to kettlebell swing exercise differs depending on load, even when total work is normalized. J Strength Cond Res 35: 997-1005, 2021.

24. Ratamess NA, Alvar BA, Evetoch TK, Housh TJ, Kibler WB, Kraemer WJ, Triplett NT. American College of Sports Medicine position stand: Progression models in resistance training for healthy adults. Med Sci Sports Exerc 41: 687-708, 2009.

25. Rhea MR, Alderman BL. A meta-analysis of periodized versus nonperiodized strength and power training programs. Res Q Exerc Sport 75: 413-22, 2004.

26. Rhea MR, Phillips WT, Burkett LN, Stone WJ, Ball SD, Alvar BA, Thomas AB. A comparison of linear and daily undulating periodized programs with equated volume and intensity for local muscular endurance. J Strength Cond Res 17: 82-7, 2003.

27. Riebe D, Ehrman JK, Liguori G, Maga, M (Editors). American College of Sports Medicine: ACSM's Guidelines for Exercise Testing and Prescription, 9th ed. Philadelphia, PA, Wolters Kluwer, 2018.

28. Schoenfeld BJ, Peterson MD, Ogborn D, Contreras B, Sonmez GT. Effects of low- vs. high-load resistance training on muscle strength and hypertrophy in well-trained men. J Strength Cond Res 29: 2954-63, 2015.

29. Shephard RJ. PAR-Q and Canadian Home Fitness Test and exercise screening alternatives. Sports Med 5: 185-195, 1988.

30. Souza EO, Ugrinowitsch C, Tricoli V, Roschel H, Lowery RP, Aihara AY, Leão AR, Wilson JM. Early adaptations to six weeks of non-periodized and periodized strength training regimens in recreational males. J Sports Sci Med 13: 604-9, 2014.

31. Stone MH, Potteiger JA, Pierce KC, Proulx CM, O'Bryant HS, Johnson RL, Stone ME. Comparison of the effects of three different weight-training programs on the one repetition maximum squat. J Strength Cond Res 14: 332-7, 2000.

32. Suchomel TJ, Nimphius S, Bellon CR, Stone MH. The importance of muscular strength: Training considerations. Sports Med48: 765-785, 2018.

33. Tan B. Manipulating resistance training program variables to optimize maximum strength in men: a review. J Strength Cond Res 13: 289-304, 1999.

34. Tibana RA, de Sousa NMF, Cunha GV, Prestes J, Fett C, Gabbett TJ, Voltarelli FA. Validity of session rating perceived exertion method for quantifying internal training load during high-intensity functional training. Sports (Basel) 6: 1-8, 2018.

35. Tsatsouline P. Enter the kettlebell. St. Paul, MN: Dragon Door Publications, Inc, 2006.

36. Tsatsouline P. Power to the people: Russian strength training secrets for every American. St. Paul, MN: Dragon Door Publications Pubn; 1st edition, 2000.

37. Turner A. The science and practice of periodization: a brief review. Strength Cond J 33: 34-46, 2011.

38. Williams T, Tolusso D, Fedewa M, Esco M. Comparison of periodized and non-periodized resistance training on maximal strength: A meta-analysis. Sports Med 47: 2083-2100, 2017.

39. Williams T, Tolusso D, Fedewa M, Esco M. Author's Reply to Nunes et al.: Comment on: "Comparison of periodized and non-periodized resistance training on maximal strength: A meta-analysis". Sports Med 48: 495-496, 2018.

40. Zebis MK, Skotte J, Andersen CH, Mortensen P, Petersen HH, Viskaer TC, Jensen TL, Bencke J, Andersen LL. Kettlebell swing targets semitendinosus and supine leg curl targets biceps femoris: an EMG study with rehabilitation implications. Br J Sports Med 47: 1192-1198, 2013.