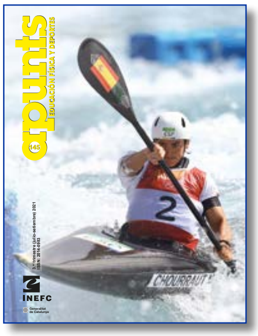
apunts EDUCACIÓN FÍSICA Y DEPORTES

Published 01 July 2021
https://doi.org/10.5672/apunts.2014-0983.es.(2021/3).145.02

ISSUE 145

SPORT TRAINING



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Comparison of the Efficacy of Three Types of Strength Training: Body, Weight Training Machines and Free Weights

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Cite this article:
Prieto-González, P. & Sedlacek, J. (2021). Comparison of the Efficacy of Three Types of Strength Training: Body, Weight Training Machines and Free Weights. *Apunts Educación Física y Deportes, 145*, 9-16. https://doi.org/10.5672/apunts.2014-0983.es.(2021/3).145.02

ISSN: 2014-0983

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Section:
Sport Training

Original language:
Spanish

Received:
10 November 2020

Accepted:
3 March 2021

Published:
1 July 2021

Cover:
Maialen Chourraut (ESP) competing in Rio de Janeiro Olympic Games (2016), Whitewater Stadium. Women's Kayak (K1) Semi-final. REUTERS / Ivan Alvarado

Abstract

The objective of this study was to verify which methodology is most effective in improving anthropometric and strength variables: training with free weights, weight training machines or body weight training. 33 male university students did strength training twice a week for eight weeks; they were divided into three training groups: body weight training (ITG), weight training machines (WMTG) and free weights (FWTG). The following variables were evaluated: body mass index (BMI), lean tissue (LT), fat percentage (% fat), sargent jump (SJ), counter-movement jump squats (CMSQ), bench presses (BP), squats (SQ), maximum relative weight in bench presses (MRW BP) and maximum relative weight in squats (MRW SQ). No significant improvements were found in the ITG in the anthropometric and strength variables. In the WMTG, there were significant improvements in % fat and strength levels, while in the FWTG there were significant improvements in % fat, LT and strength levels. Similarly, the FWTG made significant improvements compared to the WMTG in the following tests: JSQ, BP, SQ, MRW BP and MRW SQ. Eight-week strength training applied to university-age males was more effective in increasing strength and lean tissue when performed with free weights than with weight training machines. The use of body weight training did not lead to kinanthropometric or strength improvements. However, it is impossible to totally rule out the possibility that the absence of adaptations is due to the difficulties in quantifying load intensity.

Keywords: free weights, body weight training, strength, weight training machines.

Introduction

Strength training generates multiple benefits, including improved motor performance, sports performance, self-image, health conditions and quality of life, together with the prevention of pathologies and illnesses (Copeland et al., 2019; Ruiz, 2008; Seguin et al., 2013). Given its importance, the scientific community has taken an interest in studying the different factors that condition these improvements. Associations like the National Strength and Conditioning Association, the American College of Sports Medicine, the International Strength Training Association, the American Heart Association and the American Medical Society for Sports Medicine regularly publish reports containing recommendations on the development of this capacity. They also stress its importance both within the context of sport and in health in general. Nonetheless, the strength training planning often lacks scientific approaches and reflects false myths, passing fads or passionate philosophies (López-Miñarro, 2002). Thus, there is some confusion among people doing strength work, who are often unaware of the most effective way to train in order to accomplish their objectives.

In this sense, in recent decades the type of resistance used in strength training has been diversified considerably. The traditional means (bars, dumbbells, elastic bands, weight training machines and medicine balls) have been joined by elements such as vibration machines, unstable surfaces, TRX® bands and kettleballs (Lloyd et al., 2014; Raya-González and Sánchez-Sánchez, 2018). In parallel, the type of physical activity most often used to develop strength has also changed over the years. Until 2013, strength training with body weight training was not among the 20 most common fitness activities worldwide (Thompson, 2014). However, by 2015 it was the most popular, even before HIIT (high intensity interval training), of all training programmes done under the supervision of qualified professionals, conventional strength training and personalised training, which were the second, third, fourth and fifth most popular activities that year, respectively (Thompson, 2017). Different resistances and ranges of motion are used in each of them. However, even although this question sparks a heated debate in the field of physical activity and sport, the one that yields the best results has not yet been thoroughly studied (Schwanbeck, 2018).

Training with body weight training uses one's own body as resistance to work against the force of gravity. Its supporters claim that this methodology allows the exercises to be adapted to each individual's anthropometric features, making greater individualisation possible. They also argue that since the motions are executed within a closed chain, this fosters the participation of different muscle groups in each exercise. Another virtue attributed to body weight training is its effectiveness in improving relative strength, balance and posture control. In contrast, the main disadvantage is the difficulty in quantifying the workload (Harrison, 2010).

Weight training machines offer the following advantages: they are safer for the lifter and allow latter to easily learn different weight training exercises and change the weight load quickly. The disadvantages include the fact that they do not suit the anthropometric features of all subjects and do not allow much neuromuscular activation, given that they stabilise and guide the motions made by the lifter (American College of Sports Medicine, 2009).

Finally, training with free weights allows for a wider variety of motions, and these weights are more functional than weight-training machines in that they can mimic tasks from everyday life as sports gestures. Furthermore, the equipment required is inexpensive. All of this leads to better adherence to strength training. The stimulation of the stabilising musculature is greater when working with free weights than with weight training machines. However, the proper technical execution of exercises using free weights entails a certain degree of difficulty, meaning that they have a longer learning curve (American College of Sports Medicine, 2009).

Finally, bearing in mind that *a priori* the different types of resistance used in strength training have both pros and cons, it is essential to ascertain which one is the most effective. Thus, the goal of this study is to determine which of these three types of training leads to the greatest improvements in strength levels and kinanthropometric parameters: training with body weight training, weight training machines or free weights.

Methodology

Participants

Thirty-three (33) male college students [age: 20.52 (1.45); height: 176.51 (5.23); weight: 74.37 (4.95); BMI: 23.93 (1.37)] were chosen to participate in this study. None of them had experience in strength training or practised organised physical sport activities. Nor did they have any injuries or illnesses which would prevent them from doing the tests and training protocols normally. In an initial pre-study session, the participants were given information on the study's objectives, procedures and characteristics. The benefits and risks of their inclusion in it were also explained to them. They were also asked not to change either their diet or their physical sport habits during the research, to avoid doing intense physical exercise 72 hours before they took the tests, including the pre- and post-intervention, and not to ingest caffeine 24 hours before the tests. This study was conducted observing the ethical principles contained in the Declaration of Helsinki and had the approval of the Institutional Review Board of the Bioethics Committee of Prince Sultan University of Riyadh (Saudi Arabia).

Instruments

The same battery of tests was performed one week before and one week after the intervention period. In both cases, the measurements were:

Kinanthropometric evaluation. Body mass (BM), height and the body mass index (BMI) were measured using a Seca Digital Column Scale (Hamburg, Germany). BM was registered with a precision of 0.1 kg and height with a precision of 0.1 cm. The measurements were taken with the subjects barefoot and by the same researcher. Body fat percentage (% fat) was calculated with the following formula: % fat = [(∑ of abdominal, supraspinal, subscapular, tricipital, quadricipital and peroneal folds)* .143] + 4.56; (González et al., 2006). An FG1056 Harpenden skinfold calliper (Sussex, United Kingdom) was used to measure the fat folds. Lean tissue (LT) was calculated with the following formula: LT = total weight (kg) – fatty mass (kg).

Strength assessment. Before doing the tests, the participants did the following warm-up: a) activation phase, with five minutes of aerobic exercise; b) musculoarticular mobility phase, where they mobilised the main joints from head to toe; c) specific warm-up phase with a series of 10 vertical jumps with and without countermovement plus a series of 10 repetitions without reaching muscle failure in the squat and bench press exercises.

The following capacities were subsequently evaluated:

1. Jump capacity. Two tests were used: jump squat (JSQ) and countermovement jump (CMJ), measured by means of the Optojump device (Bolzano, Italy). In order to prevent the differences in the jump technique among the participants from compromising the validity of the results of both tests, the subjects placed their hands on their hips during the exercise. Both tests were conducted following the protocol of Bosco et al. (1981).

The JSQ started with a 90° knee flexion, with the trunk upright. The jumper then executed a concentric contraction of the knee extensor muscles and kept the trunk vertical during the flight phase. In the CMSQ, they started standing on both feet. The test started with a quick flexion of the knees until a 90º angle was reached. Immediately after that, the subject executed a concentric contraction of the knee extensor muscles, while keeping the trunk vertical. Each participant had two tries in both the JSQ and the CMSQ and only the best result was recorded.

2. Maximum strength. Two tests were performed: squat (SQ) and bench press (BP). The SQ was used to measure maximum lower-body strength. An Olympic bar and Olympic disks were used. Starting by standing on two feet, the subjects placed the Olympic bar on the upper fibres of the trapezius muscle while their feet were at shoulder's width distance apart. They were then asked to flex their knees until their thighs were parallel to the floor. They then had to return to their initial position. Similarly, the BP was used to measure maximum upper-body strength. To do this test, the subjects lay prone on a Hammer Strength bench-press bench with their head and hips in the neutral position. They were then instructed to grasp the bar with their hands at shoulders' width distance apart. Starting from this position, with their elbows extended, they had to lower the bar until it made contact with their chest and then raise it back to its initial position (National Strength and Conditioning Association, 2017). In both the squat and the bench press, the better result of two tries was recorded. Given that the subjects lacked strength training experience, the 1RM was calculated using the Lander formula (Felipe et al., 2013). Both tests were done with 80 % of each subject's estimated 1RM and only the number of repetitions executed correctly was recorded.

3. Relative maximum strength. Once each subject's 1RM in the squat and bench press had been estimated, the relative weight in the bench press (MRW BP) and the squat (MRW SQ) were calculated. For this purpose, the Wilks coefficient was used with the following formula: coefficient = $500/ a + bx + cx^2 + dx^3 + ex^4 + fx^5$; with (for men): x = the subject's BM in kg; a = -216.0475144; b = 16.2606339; c = -.002388645; d = -.00113732; e = 7.01863E-06; f = -1.291E-08. This formula is a valid method for comparing the subjects' relative strength with different weights given that the body mass multipliers favour people with light weights and do not consider allometric relations (García-Manso et al., 2010).

Procedure

Once they had completed the pre-test, the 33 subjects included in the study were divided into three experimental groups: body weight training training group (ITG), weight training machine training group (WMTG) and free weights training group (FWTG). In order to give the study greater internal consistency, make the groups more homogeneous and lower intergroup variance, the following procedure was used to assign the subjects to each of the three experimental groups: according to their scores in the 1RM test in the squat, the participants were divided into 11 clusters, each one comprised of three subjects. The three subjects with the top scores were assigned to cluster one, the subjects with the fourth, fifth and six scores to cluster two and so on. After that, to avoid the influence of possible extraneous variables not assigned to clusters, each of the three members of the 11 groups was assigned randomly to one of the three different experimental groups.

The intervention lasted eight weeks. The programme observed the principles of sports training and the recommendations of the American College of Sports Medicine for strength training with beginners. In summary, three series of each exercise were done, from 6 to 12 repetitions per series, and the rest time lasted between one and two minutes. In the training session, the exercises meant to strengthen the larger muscle groups were performed before those intended for the smaller muscle groups, and multi-joint exercises were performed before single-joint exercises. Eccentric and concentric contractions were included (American College of Sports Medicine, 2009).

The training parameters applied to the three groups were identical (Table 1); however, the exercises were different in each of the groups (Table 2).

To estimate the intensity of the training in the WMTG and in the FWTG, during the week of the pre-test, 1RM was calculated for the exercises used by both groups with the Lander test. Subsequently, during the intervention, the OMNI-RES strength training scale was used (Robertson et al., 2013) to even out the intensity of the training in all three groups. Similarly, in all the training sessions, special attention was paid to ensure that the kind of effort used while doing each exercise (as with the other training parameters) was identical for all three groups.

Table 1
Features of the training applied to the three experimental groups.

	Weeks 1 and 2	Weeks 3 and 4	Weeks 5 and 6	Weeks 7 and 8
Intensity	62 %	62 % - 67 % - 72 %	72 %	76 %
Series	3	3	3	3
Repetitions	12	12 - 10 - 8	8	6
Rest	1’	1’ 30”	2	2
Type of effort	Highest number of repetitions possible per set			

Table 2
Strength exercises used by each of the three experimental groups.

	ITG	WMTG	FWTG
Trunk flexors	Abdominal crunch	Abdominal crunch on machine	Weighted crunches
Trunk extensors	Pelvis lifts	Machine back extension	Roman chair weighted back extension
Leg	Step up and Bulgarian split squat	Leg presses	Lunges with Olympic bar
Pectoral	Push-ups	Chest press	Dumbbell press
Back	Pull-ups (horizontal, oblique and vertical position) wide back grip	Rowing machine	One arm dumbbell row
Elbow extensors	Bench dips (hands separated at shoulder’s width)	Triceps on triceps dip machine	Triceps kickback
Elbow flexors	Pull-ups (horizontal, oblique and vertical position) palm grip at shoulder’s width	Biceps curl on Scott machine	Alternative dumbbell curl

Note. ITG: body weight training group; WMTG: weight training machine training group; FWTG: free weights training group.

Statistical analysis

The results were analysed using the IBM SPSS V.22® computer program. The data were presented using the mean arithmetic format (standard deviation). The Shapiro-Wilk test was used to check the normality of the distribution and the Levene test to verify the homogeneity of the variances. To assess the effect of the training, a two-factor repeated measures ANOVA (RM ANOVA) was conducted. When significant *p* values were found, a *post hoc* analysis was conducted with Bonferroni correction to identify the differences. The intra-subject effect size was calculated with Cohen's *d*, considering $d = .2$ small, $d = .5$ medium and $d = .8$ large. The inter-subject effect size was estimated using the eta-squared parameter (η2), with η2 values = .1, .25, and .40 considered small, medium and large effect sizes, respectively (Cohen, 1988). The level of significance established was $p = .05$.

With regard to inter-subject differences, the *post hoc* analysis showed that the improvements obtained by the FWTG after the intervention process were significantly higher than those obtained by the ITG in all the strength tests (JSQ: $p = .023$; CMSQ: $p = .003$; BP: $p = .002$; SQ: $p = .035$; MRW BP: $p = .007$; MRW SQ: $p = .036$). The FWTG also showed significantly higher improvements than those of the WMTG in all the strength tests, except the CMSQ (JSQ: $p = .014$; BP: $p < .045$; SQ: $p = .004$; MRW BP: $p < .041$; MRW SQ: $p < .018$). In contrast, there were no significant differences between the improvements attained by the WMTG and the ITG.

With regard to intra-subject comparisons (Table 3), the ITG showed no significant improvements in any of the variables analysed. The WMTG showed significant improvements in all the strength parameters and % fat. Finally, the FWTG showed significant improvements in all the strength measures, % fat and LT.

Results

No differences were observed among the groups in any of the dependent variables evaluated before the start of the training. The RM ANOVA indicated the absence of a time*group interaction and of a principal effect of time in the BM and BMI. In contrast, the existence of a principal effect of time was verified in the LT ($p = .01$; η2 = .247) and in % fat ($p = .002$; η2 = .650). Similarly, a time*group interaction was found for the following variables: JSQ ($p = .02$; η2 = .325), CMSQ ($p = .007$; η2 = .389), BP ($p = .001$; η2 = .594), SQ ($p = .001$; η2 = .58), MRW BP ($p = .000$; η2 = .564) and MRW SQ ($p = .000$; η2 = .547).

Discussion

This study has shown that eight weeks of training with body weight training did not lead to kinanthropometric improvements. The WMTG managed to lower % fat, while the FWTG not only lowered % fat but also increased lean tissue. From these results, we can glean that training with free weights is the most effective of the techniques to achieve changes in body composition. However, given that the effect sizes in both the WMTG and the FWTG were small, it is also possible to posit that attaining substantial improvements in body composition requires the application of strength training for considerably longer than eight weeks.

Table 3
Changes recorded in the kinanthropometric variables and strength levels after the application of the three training protocols.

	Group	Pre-test	Post-test	Cohen's *d*	*P*
BM	ITG	74.5 (4.64)	74.3 (4.63)	0.04	.14
	WMTG	74.4 (5.83)	74.5 (5.81)	0.01	.36
	FWTG	74.2 (4.77)	74.5 (4.93)	0.06	.11
BMI	ITG	23.98 (1.22)	23.95 (0.98)	0.02	.90
	WMTG	23.88 (1.60)	23.78 (1.61)	0.06	.47
	FWTG	23.94 (1.39)	24.03 (1.40)	0.06	.12

Note. BM: body mass; BMI: body mass index; LT: lean tissue; % fat: fat percentage; JSQ: jump squats; CMSQ: counter-movement jump squats; BP: bench presses; SQ: squats; MRW BP: relative maximum strength in bench presses; MRW SQ: relative maximum strength in squats; ITG: body weight training training group; WMTG: weight training machines training group; FWTG: free weights training group; *: significant improvement between the pre-test and post-test; +: significant improvement between the FWTG and the ITG; #: significant improvement between the FWTG and the WMTG.

Table 3 (Continuation)
Changes recorded in the kinanthropometric variables and strength levels after the application of the three training protocols.

	Group	Pre-test	Post-test	Cohen's *d*	*P*
LT	ITG	62.16 (3.42)	62.11 (3.41)	0.01	.52
	WMTG	61.97 (4.23)	62.08 (4.23)	0.02	.62
	FWTG	61.87 (3.35)	62.31 (3.54)	0.12	.02*
% fat	ITG	16.54 (1.25)	16.39 (1.25)	0.11	.101
	WMTG	16.60 (1.59)	16.38 (1.50)	0.14	.0001*
	FWTG	16.57 (1.41)	16.30 (1.55)	0.18	.0063*
JSQ	ITG	31.90 (2.12)	32.46 (1.91)	0.27	.10
	WMTG	31.7 (2.17)	32.6 (2.20)	0.41	.0001*
	FWTG	31.60 (1.90)	33.12 (1.65)	0.85	.0001*+#
CMSQ	ITG	35.05 (1.91)	35.63 (1.79)	0.31	.14
	WMTG	34.96 (2.31)	36.58 (2.41)	0.68	.0001*
	FWTG	34.61 (1.88)	37.25 (1.30)	1.63	.0003*+
BP	ITG	53.40 (6.07)	54.90 (4.02)	0.28	.25
	WMTG	53.1 (6.31)	55.9 (6.67)	0.43	.001*
	FWTG	53.30 (4.08)	60.90 (4.83)	1.69	.000*+#
SQ	ITG	82.32 (6.5)	84.57 (7.5)	0.32	.19
	WMTG	82.27 (5.70)	85.87 (5.39)	0.64	.0001*
	FWTG	81.88 (5.50)	91.43 (6.67)	1.56	.0001*+#
MRW BP	ITG	38.63 (5.78)	39.46 (4.28)	0.16	.41
	WMTG	38.18 (4.88)	40.19 (4.97)	0.41	.002*
	FWTG	38.31 (1.94)	43.72 (2.02)	2.73	.0001*+#
MRW SQ	ITG	59.25 (6.39)	60.91 (6.20)	0.26	.18
	WMTG	59.30 (5.17)	61.89 (4.95)	0.51	.0001*
	FWTG	58.89 (2.61)	65.58 (3.03)	2.36	.0001*+#

Note. BM: body mass; BMI: body mass index; LT: lean tissue; % fat: fat percentage; JSQ: jump squats; CMSQ: counter-movement jump squats; BP: bench presses; SQ: squats; MRW BP: relative maximum strength in bench presses; MRW SQ: relative maximum strength in squats; ITG: body weight training training group; WMTG: weight training machines training group; FWTG: free weights training group; *: significant improvement between the pre-test and post-test; +: significant improvement between the FWTG and the ITG; #: significant improvement between the FWTG and the WMTG.

Nor did the ITG achieve significant improvements in strength levels. This finding concurs with the study conducted by Martínez and Cuadrado (2003) with handball players. These authors demonstrated that traditional strength training and combined training (strength exercises chained with explosive movements) are effective in improving maximum strength and explosive strength, while training with body weight training did not generate significant improvements in those two manifestations of strength. However, the reason why training with body weight training is not effective in improving strength and kinanthropometric variables is not entirely clear. One of the reasons may be that there is less muscle stimulation with this methodology, even when the kind of effort is identical to load-bearing exercises. Another possible cause is the lower functionality of the exercises compared to those performed with free weights due to the fact that when body weight training is used, angles and working positions have to be modified to graduate the intensity of the exercises, meaning that less natural positions are sometimes used. Nonetheless, we cannot totally rule out the possibility that the absence of adaptations is due to the difficulties in quantifying the intensity of the training performed with body weight training.

In contrast, the WMTG and FWTG improved results in all the strength tests conducted. Furthermore, the training with free weights was more effective at increasing maximum strength, explosive strength and relative maximum strength than the weight training machines. These results differ from those of Schwanbeck (2018) in a study also conducted with university-age students which found that both weight training machines and exercises done with free weights generate similar increases in LT and strength. In a similar vein, after systematic reviews of different studies on strength, the American College of Sports Medicine (2009) and Fisher et al. (2011) concluded that both methodologies generate similar improvements in strength.

However, other studies results concur with those of this study. Wirth et al. (2016) compared the efficacy of strength training of the lower body using squats and leg presses. The group that trained with squats achieved better results in the JSQ and the CMSQ. The authors attribute this to the higher functionality of squats and their greater similarity to the jump test compared to the leg press. In a similar study comparing the same two exercises, Shaner et al. (2014) verified that squats generate an acute response in growth hormone, testosterone and cortisol, in addition to a higher heart rate and higher lactate concentration. Another earlier study (Shaner, 2012) also found that the acute release of testosterone and of growth hormone is higher after doing squats than after doing leg presses. However, in addition to hormonal factors, another reason why training with free weights may be more effective than weight training machines is that the stabilisation requirements are higher in exercises with free weights, and this requires greater muscle activation (García and Requena, 2011). Fletcher and Bagley (2014) and Schick et al. (2010) also point out that the advantage of doing squats with a bar compared to a Smith machine is that the stabilisation requirements take place on the three planes of motion. Thus, the coordinative difficulty of the exercise is higher, given that the exerciser has to control both load and movement, while also synchronising the actions performed by a greater number of fixator, synergistic and antagonistic muscles. These authors also stress the higher functionality of the squat and believe that the transfer of the strength gains from the squat to other motor situations is more feasible than working with machines that stabilise movement. Here, we should recall that in order to avoid the learning effect, the strength exercise used by the FWTG during the intervention to develop lower-body strength (lunges with bar) in this study was different to what was used with the three experimental groups in the pre-test and post-test to evaluate their lower strength (squats). Nonetheless, the improvements in strength obtained by the FWTG are significantly higher than those in the other two groups; therefore, we can interpret that lunges are also more functional than leg presses.

In consequence, based on the results of this study and bearing in mind those of previous studies, we would assert that when the objective of training is to increase maximum strength or explosive strength, it is better to use exercises with free weights. Weight training machines can also be used, as they also yield improvements in strength levels. But it should be remembered that several studies concur that these improvements may be lower than those achieved with free weights. With regard to body weight training, current scientific evidence tells us that it does not allow for significant improvements in body composition or strength levels. Consequently, it should be used only if there is no possibility of training using free weights or weight training machines. Nonetheless, further studies are needed to confirm that training with free weights yields better results than weight training machines and that the latter are more effective than body weight training.

To conclude, we should mention that the main limitation of this study was the small sample size. A larger number of participants would have afforded this research greater statistical power.

Conclusion

An eight-week strength training applied to university-age males was more effective in increasing strength and lean tissue when done with free weights than with weight training machines. The use of body weight training did not generate kinanthropometric or strength improvements. However, in this latter case we cannot totally rule out the possibility that the absence of adaptations is due to the difficulties in quantifying load intensity.

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Conflict of Interests: No conflict of interest was reported by the authors.