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Effects of 12 weeks of short-duration isometric strength training in university students

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Abstract: Purpose: Isometric strength training has the advantage of improving musculoskeletal properties, neuromuscular function and health biomarkers compared with dynamic strength training. This study aimed to analyze the effects of short-term isometric strength training on pain, body composition, and biomarkers of health in young adults. Methods: This was a pre-post experimental study with isometric training period. The training period was carried out for 12 weeks with a single session per week, with a weekly training volume of 6 minutes. The study sample consisted of 22 students (20.5 years ± 1.37) of both sexes (15 males and 7 females). The maximum isometric force test (in Newton meters) using the MedX lumbar extension and knee extension machines. The InBody 770 were used for body composition analysis, visual analog scale for pain and glycated hemoglobin values were measured using the Quo-Lab. Results: Analysis of changes in pain showed a significant improvement in hip pain in the entire group ($p \le 0.05$), with no other significant changes observed in the other pain scales (0.05), phase angle (0.02), glycated haemoglobin (0.00) and lumbar strength (<0.05) measured or segregating the sample by sex. Conclusion: The study demonstrates that a short duration strength training intervention can help to improve pain at anatomical points, reduce HbA1c levels, finding trends for improvement in numerous body composition variables. Highlighting the significant change in phase angle, a variable with a promising approach in the more accurate and comprehensive study of both body composition and metabolic health.

Keywords: Young adults; isometric training; phase angle; pain; HbA1

1. Introduction

Resistance training is based on the systematic application of loads to develop and improve strength, muscle hypertrophy, and/or neuromuscular adaptations (Buckner et al., 2017). Muscle strength is defined and measured as the greatest amount of weight an individual can lift concentrically, usually in the form of a one-repetition maximum (1RM) test. Although 1RM tests are the most widely used, there are other strength tests such as isokinetic or isometric tests (Spitz et al., 2023). Increased muscle mass and strength are major elements in the context of sports conditioning. Moreover, preserving adequate muscle mass is also of significant relevance in terms of health (Krzysztofik et al., 2019).

Isometric strength training is performed when a muscle generates force and attempts to shorten but does not overcome external resistance, and involves exercises that are performed while maintaining the same length in the muscle (Egan & Sharples, 2023). This type of training has the advantage of improving musculoskeletal properties and neuromuscular function compared with dynamic strength training (Oranchuk et al., 2019). In addition, it helps strengthen the muscles that surround the joints, providing greater stability, reducing the risk of injury (Legerlotz, 2020), and enhancing the coactivation of synergistic muscles (Tillin et al., 2011).

False myths about strength training have been created among young adults, but an increasing number of interventions have reported benefits in this population (Faigenbaum et al., 2009, 2022; Riebe et al., 2018). Studies highlight the fundamental role of physical exercise in normal growth and development as well as in the reduction of chronic disease risk throughout the lifespan (Faigenbaum, 2007; Rowland, 2007). In addition, it contributes to a reduced risk of injury and improves performance and health in young and younger adults (Lloyd & Oliver, 2019). Many of the benefits of resistance training programs for adults are applicable to children, adolescents, and young adults (J. J. Smith et al., 2014). Consequently, this type of training is currently gaining universal acceptance by medical and sports organizations (Lloyd et al., 2014; Riebe et al., 2018). There are multiple programs focused on strength development that significantly benefit the youth and young adult population by improving strength (Dahab & McCambridge, 2009; Krzysztofik et al., 2019; Weiss et al., 2010; Westcott, 2012). Additionally, these programs generate benefits, such as improved physical function, bone density, balance, personal self-esteem, metabolic profiles, and body composition (Faigenbaum et al., 2022; Layne & Nelson, 1999; Trujillo, 1983; Weiss et al., 2010; Westcott, 2012).

The intensity and volume of strength training are fundamental factors that directly affect muscle adaptation (Krzysztofik et al., 2019; Schoenfeld et al., 2017). Although international institutions have established specific guidelines (Bayles & Swank, 2018), there is a wide variety of training options in the current literature (Fyfe et al., 2022). Scientific evidence indicates that minimal doses of strength training with lower session volumes than traditional guidelines can improve strength and functional capacity in young adults (Fyfe et al., 2022).

Several studies have provided proposals for the minimum dose of strength training in different populations (Androulakis-Korakakis et al., 2020; Fisher et al., 2017; Fyfe et al., 2022; Iversen et al., 2021; Steele et al., 2022), which vary depending on the load applied (Fyfe et al., 2022). With loads that do not exceed 85% of RM, it is recommended to perform 2-3 training sessions per week with a maximum duration of 60 min, performing 6-12 repetitions (Androulakis-Korakakis et al., 2020; Fisher et al., 2017). Other authors have concluded that reducing the frequency of training to a single repetition once a week and performing six exercises to failure is sufficient to obtain health benefits. These training methods report benefits in terms of strength levels and biomarkers of health (Steele et al., 2022). However, little is known about the benefits of different strength training methods on some biomarkers, such as glycated hemoglobin (HbA1c) (Califf, 2018) and phase angle (PA) (Custódio Martins et al., 2022; Mullie et al., 2018), which are important variables that would help to expand knowledge about health indicators (Bučan Nenadić et al., 2022).

Therefore, this study aimed to analyze the effects of short-term isometric strength training on pain, body composition, and biomarkers of health in young adults.

2. Materials and Methods

Study design - This study is a single-group pre-experimental study with a 12-week training intervention.

Participants - The participants were selected by non-probabilistic convenience sampling from a group of young people (18-23 years old) from the Degree in Physical Activity and Sport Sciences of the University of Deusto. The study sample consisted of 22 students (20.5 years ± 1.37) of both sexes (15 males and 7 females) (Table 1). All participants performed strength training in their sport modalities and they had previous experience with the two exercises used in this study.

The study was approved by the Ethics Committee of the University of Deusto (reference # ETK-3/21-22) and written informed consent was obtained from each participant prior to the start of the study.

Procedures - Data collection was performed on two occasions, one week before the intervention (pre-test, on two consecutive days) and one week after the intervention (post- test, in two days).

The measurements of pain scale, body composition and health biomarkers were taken in the physiology laboratory of the University of Deusto (temperature, 20-21ºC; relative humidity, 50-55%; barometric pressure, 755-765 mmHg). We also measured the maximum isometric strength of lumbar extension and knee extension at the Ikaika Center (https://ikaikatraining.com/).

Previously of the intervention participants signed the informed consent form and completed the subjective pain perception questionnaire by anatomical areas (back, knee and hip), using a visual analog scale (VAS), with ranges between 1 and 10 (Vicente Herrero et al., 2018).

Table 1. Description of the sample at the start of the study.

	Women	Men	Total
N	7	15	22
Age (years)	21.0 ± 1.41	20.3 ± 1.3	20.5 ± 1.37
Height (cm)	167.5 ± 7.56	179.05 ± 9.03	175 ± 10.1
Weight (kg)	61.06 ± 10.06	72.67 ± 8.98	69.0 ± 10.6
BMI (kg/m^2)	21.7 ± 2.62	22.65 ± 1.84	22.4 ± 2.11

Notes: Values represented in mean ± standard deviation; N = study population.; BMI = Body Mass Index.

After that, in the same day, they were measured using a Seca 206 (Seca GmBH & Co Kg, Hamburg, Germany) portable stadiometer followed by the Inbody 770 (InBody Europe, Amsterdam, The Netherlands) bioimpedance test (Inbody, 2014). Prior to these measurements, participants were asked to follow the corresponding protocol: not to perform intense physical exercise, not to consume alcohol or caffeine in excess during the 24 hours prior to the test, not to eat or drink 4 hours before the test, with the exception of water up to 45 minutes before the test to maximize its reliability (McLester et al., 2020). With this test, weight (kg), skeletal muscle mass (kg), body fat mass (kg), fat-free mass (kg), basal metabolic rate (kcal) and phase angle (º) were recorded. Subsequently, HbA1c values were measured using the Quo-Lab (EKF Diagnostics PLC, Cardiff, UK) HbA1c device, collecting HbA1c values and estimated mean glucose. To perform this test, a capillary sample was taken from the index finger.

On a second day, prior the intervention, they performed the maximum isometric force test (in Newton meters) using the MedX (MedX, Altamonte Springs, FL, USA) lumbar extension and knee extension machines (Figure 1), recording the force at angles 72°, 60°, 48°, 36°, 24°, 12°, 0°, and 108°; 96°, 78°, 60°, 42°, 24°, and 6° respectively (Graves et al., 1990; Pollock et al., 1989). To perform the measurement, the joint arm was locked at the corresponding joint angle predetermined by the measurement. In addition, the participant was instructed to progressively increase the tension for 2-3 seconds to its maximum isometric contraction, maintaining this contraction for 1 second more. This was followed by a 10-second rest before they moved on to the next angle test (D. Smith et al., 2011).

Figure 1. MedX lumbar extension and knee extension machines.

Training - The training period was carried out for 12 weeks with a single session per week (Bruce-Low et al., 2012), with a weekly training volume of 6 minutes.

The training consisted of performing the two exercises isometrically at three different angles (Lum et al., 2019), lumbar extension (72º, 48º, 0º) and knee extension (108º, 54º, 6º), in all training sessions the subjects were accompanied by two of the researchers.

In each angle a 15-second contraction was performed, the first 5 seconds to perform a progression to maximum isometric strength and then 10 seconds trying to maintain the maximum ("all-out effort", with verbal support) possible strength with 10-second rests between each angle. Emerging research suggests that subjective perceptions of effort may be not only suitable but also potentially more informative than traditional objective measures for monitoring exertion (Montull et al., 2022). With a total weekly volume of 250 seconds of training of which 90 seconds are performing the isometric contraction and 160 in rests (in each exercise with 3 contractions of 15 seconds with 10 seconds of rest and 2 minutes of rest between exercises).

Statistical Analysis - The variables analyzed in this study are presented as mean and standard deviation. Jamovi (version 2.3.18) and Rstudio was used for their analysis. Parametric tests were carried out after testing the normality of the variables and the research groups. The significance level was established at $p \leq 0.05$ for the statistical analysis. Cohen's d was also performed to study ES. Thresholds for effects were: 0.20 "small", 0.50 "medium" and 0.80 "large" (Cohen & Cohen J., 1988). Student's t-test for paired samples was used to determine whether there were improvements between pre-intervention and post intervention data. In addition, Pearson correlations were used for the relational analysis.

Figure 1 **Figure 2.** Differences in lumbar strength pre-post intervention in the different grades evaluated.

3. Results

Analysis of changes in pain showed a significant improvement in hip pain in the entire group (p= 0.05), with no other significant changes observed in the other pain scales measured or segregating the sample by sex.

Table 2 shows the differences obtained for the distinct variables measured with respect to pain. It was found that after the exercise intervention only significant improvements were obtained in hip pain (p= 0.05).

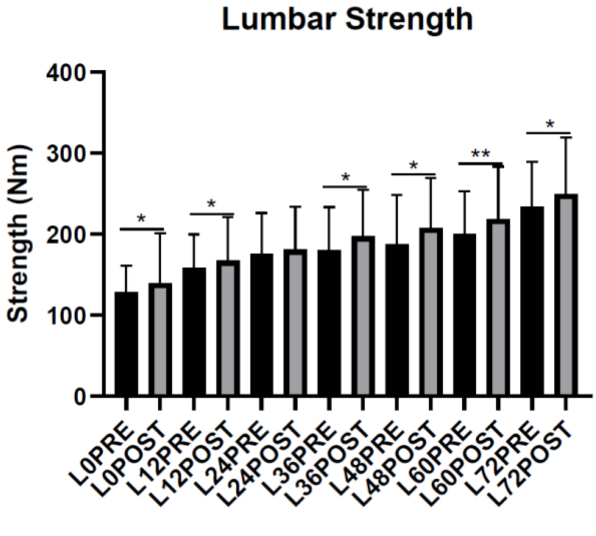
Table 3 refers to the results of the bioimpedance analysis, obtaining a significant improvement in the phase angle and observing a positive trend in all other variables.

In addition, significant improvements in glucose-related parameters have been demonstrated (Table 4).

Regarding the muscle strength of the whole group, significant differences were only observed in the lumbar extension exercise in all the angles except in the 24º angle. In angles 0, 12, 36, 36, 48, 60 and 72 = p≤0.05 (Figure 2).

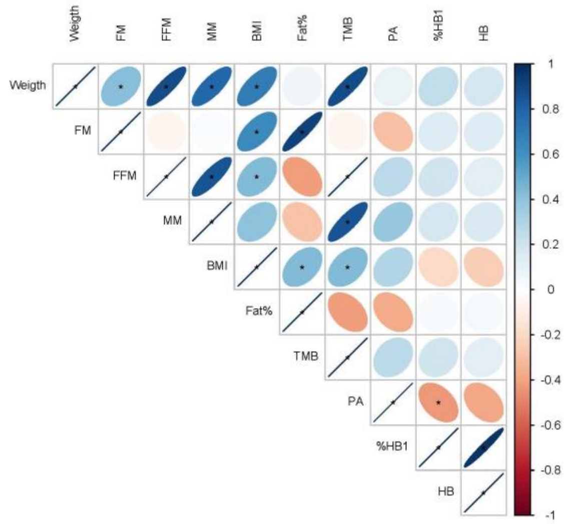
When correlating the variables analyzed in the exercise intervention (Figure 3), it is observed that there is significance (p≤0.05) between the variables of phase angle with % fat (r = -0.43) and %HBA1c (r = -0.45), however, it should be noted that this is a low negative correlation.

Figure 2. Differences in lumbar strength pre-post intervention in the different grades evaluated.



Notes: * = p<0,05; ** = p<0,001; L = Lumbar Extension Strength; 0, 12, 24, 36, 48, 60, 72 = angles where strength is applied; PRE = Pre-intervention; POST = Post-intervention

Figure 3. Correlation between variables of the entire group.



Notes: FM = Fat Mass; FFM = Fat Free Mass; MM = Muscle mass; BMI = Body Mass Index; Fat% = Fat Percentage; TMB = Basal Metabolic Rate; PA= Phase Angle; %HB1 = Glycated Haemoglobin percentage; HB =Mean Glucose.

Table 2. Perceived pain before and after the exercise intervention

Variables		Pre-test	Post-test	Student´s T	*p* value	Cohen´s *d*	95% confidence interval	
		Mean ± SD					Lower	Upper
Back pain	Women	0.71 ± 1,25	1.14 ± 2.04	-1.00	0.35	-0.37	-1.13	0.40
	Men	1.66 ± 2.09	1.66 ± 2.29	0	1.00	0.00	-0.50	0.50
	Total	1.36 ± 1.89	1.50 ± 2.13	-0.42	0.67	-0.089	-0.50	0.33
Knee pain	Women	0	0	0	0	0	0	0
	Men	0.86 ± 1.88	0.66 ± 1.29	0.52	0.60	0.13	-0.37	0.64
	Total	0.59 ± 1.59	0.45 ± 1.10	0.53	0.60	0.11	-0.30	0.53
Hip pain	Women	1.00 ± 1.91	0.42 ± 1.13	1.54	0.17	0.58	-0.24	1.37
	Men	1.26 ± 1.58	0.60 ±1.40	1.58	0.13	0.40	-0.12	0.92
	Total	1.18 ± 1.65	0.54 ± 1.30	2.08	0.05*	0.44	7.85e-4	0.87

Notes: SD = standard deviation

Table 3. Changes in body composition

Variables		Pre-test	Post-test	Student´s T	*p* value	Cohen´s *d*	95% confidence interval	
		Mean ± SD					Lower	Upper
Weight (kg)	Women	61.06 ± 10.6	60.47 ± 10.58	1.19	0.27	0.45	-0.34	0.12
	Men	72.67 ± 8.98	72.54 ± 8.70	0.38	0.70	0.09	-0.41	0.60
	Total	68.97 ± 10.64	68.70 ± 10.75	1.00	0.32	0.21	-0.21	0.63
Fat mass (kg)	Women	13.43 ± 5.87	12.79 ± 6.47	2.00	0.09	0.75	-0.11	0.15
	Men	9.15 ± 3.75	9.27 ± 4.07	-0.38	0.70	-0.09	-0.60	0.41
	Total	10.51 ± 4.84	10.39 ± 5.08	0.46	0.64	0.09	-0.32	0.51
Fat percentage (%)	Women	21.46 ± 6.04	20.44 ± 6.32	1.90	0.10	0.71	-0.14	0.15
	Men	12.51 ± 4.21	12.55 ± 4.48	-0.08	0.93	-0.02	-0.52	0.48
	Total	15.36 ± 6.36	15.06 ± 6.24	0.79	0.43	0.16	-0.25	0.58
Fat free mass (kg)	Women	47.63 ± 5.92	47.69 ±5.50	-0.10	0.91	-0.04	-0.78	0.70
	Men	63.52 ± 7.66	63.27 ± 6.81	0.58	0.56	0.15	-0.36	0.65
	Total	58.46 ± 10.32	58.31 ± 9.73	0.46	0.64	0.09	-0.32	0.51
Musculoskeletal mass (kg)	Women	26.41 ± 3.51	26.56 ± 3.31	-0.45	0.66	-0.17	-0.91	0.58
	Men	36.13 ± 4.56	36.07 ± 4.04	0.23	0.81	0.06	-0.44	0.56
	Total	33.04 ± 6.23	33.05 ± 5.88	-0.02	0.98	-0.00	-0.42	0.41
BMI (kg/m^2)	Women	21.70 ± 2.62	21.49 ± 2.92	1.22	0.26	0.46	-0.33	0.12
	Men	22.65 ± 1.84	22.60 ± 1.73	0.52	0.61	0.13	-0.37	0.64
	Total	22.35 ± 2.10	22.25 ± 2.17	1.18	0.25	0.25	-0.17	0.67
Basal metabolic rate (kcal)	Women	1399 ± 127	1399 ± 118	-0.03	0.97	-0.01	-0.75	0.72
	Men	1741 ± 165	1736 ± 147	0.51	0.61	0.13	-0.37	0.63
	Total	1632 ± 222	1629 ± 210	0.43	0.66	0.09	-0.32	0.51
Phase Angle (º)	Women	5.99 ± 0.26	6.17 ± 0.51	-1.45	0.19	-0.54	-1.33	0.27
	Men	6.69 ± 0.52	6.81 ± 0.48	-1.77	0.09	-0.45	-0.98	0.08
	Total	6.47 ± 0.56	6.60 ± 0.56	2.33	0.02*	-0.49	-0.93	-0.04
Thigh circumference (cm)	Women	57.00 ± 4.39	55.47 ± 3.03	1.91	0.10	0.72	-0.14	1.54
	Men	54.82 ± 3.25	54.53 ± 3.08	0.77	0.45	0.19	-0.31	0.70
	Total	55.51 ± 3.69	54.83 ± 3.11	1.84	0.07	0.39	-0.04	0.82

Notes: SD = standard deviation; BMI= body mass index.

Table 4. Changes in glycated hemoglobin and mean glucose.

Variables		Pre-test	Post-test	Student´s T	*p* value	Cohen´s *d*	95% confidence interval	
		Mean ± SD					Lower	Upper
HBA1c	Women	5.01 ± 0.21	4.99 ± 1.95	0.31	0.76	0.11	-0.63	0.85
	Men	5.23 ± 0.16	5.01 ± 0.16	5.91	< .001*	1.52	0.75	2.27
	Total	5.16 ± 0.16	5.00 ± 0.20	3.81	0.001*	0.81	0.32	1.29
Mean glucose	Women	31.19 ± 2.23	31.11 ± 1.95	0.07	0.94	0.02	-0.71	0.76
	Men	33.58 ± 1.73	31.23 ± 1.62	3.61	0.002*	0.77	0.28	1.24
	Total	32.82 ± 2.17	31.20 ± 1.68	3.61	0.002*	0.77	0.28	1.24

Notes: SD = standard deviation; HBA1c= Glycated Haemoglobin percentage

4. Discussion

This study aimed to analyze the effects of short-term isometric strength training on pain, body composition and health biomarkers in young adults. The results of this study showed that short-duration isometric strength training can influence pain, strength levels, and some health biomarkers.

Our results suggest that strength training can positively influence hip pain. Other authors obtained similar results, observing that after 6 weeks of heavy resistance training, the subjects presented 0/10 pain and clinically important improvements in the Lower Extremity Functional Scale(Cranmer & Walston, 2022). However, we were unable to observe significant differences in the knee and back anatomical areas, results similar to other researchers(Río et al., 2022). Still, the results show a tendency for improvement in the knee (0.59 ± 1.59 vs. 0.45 ± 1.10), as observed in other investigations with knee pain (Nascimento et al., 2018). Against all odds, worsening of low back pain was observed (1.36 ± 1.89 vs. 1.50 ± 2.13). This result is consistent with other studies that conclude that the prevalence of musculoskeletal pain among university students is high (Hasan et al., 2018; Penkala et al., 2018). One of the characteristics of the participants was that they were physically active and reported low levels of pain, as in previous studies that have shown that active people tend to experience less pain than those who are inactive or sedentary (Lindell & Grimby-Ekman, 2022).

The study results indicate the values of a healthy, non-obese population when analyzing muscle and fat profiles, in line with the reference values provided by the ACSM (Riebe et al., 2018). (Riebe et al., 2018). In addition, no significant changes were observed in the lipid and muscle profile variables obtained for bioimpedance or thigh circumference. Previous studies have also analyzed the influence of strength training on muscle profiles in healthy individuals, observing no significant changes in hypertrophy (Lopez et al., 2021; Mcleod et al., 2024). This may be due to the fact that contractions at maximum intensity do not exceed 10 seconds in duration, and in such short efforts less hypertrophy can be observed (Lum & Barbosa, 2019). Another factor may be the frequency of training; previous studies have shown that one day of training results in less muscle hypertrophy than training proposals with multiple weekly training days (Ochi et al., 2018). This could be interesting for sports where weight can be a limiting factor, because there is no significant change in either weight, muscle mass gain, or leg circumference, but there is metabolic and muscle strength improvement.

However, we did find changes in PA (6.47 ± 0.56 vs. 6.60 ± 0.56; p≤0.05; Cohen's d= 0.498). It is a useful tool for identifying cell membrane integrity and function (Barbosa-Silva et al., 2005). PA is associated with different biomarkers of health, including muscle strength (Norman et al., 2015). Strength training has been shown to significantly improve PA, as observed by improvements in PA after a 12-week training period (Campa et al., 2018; Nunes et al., 2019). Similar results were obtained in a strength training intervention designed with three days per week of training aimed at increasing muscle hypertrophy in young male and female college students (Ribeiro et al., 2015).

In addition, the results of the study also indicated significant changes in HbA1c (5.16 ± 0.16 vs. 5.00 ± 0.16; p<0.001; Cohen's d= 0.813). HbA1c is a biomarker that reflects blood glucose levels during the last three months (American Diabetes Association, 2013). These findings are consistent with recent meta-analyses that recommend an optimal range of 5.0-6.0% HbA1c to prevent mortality risks in non-diabetic populations (Cavero-Redondo et al., 2017, 2018).

Although favorable results have previously been demonstrated following exercise interventions in diabetic individuals (Jansson et al., 2022). Our data support that strength training has also a positive effect on HbA1c levels in healthy individuals even when low training volumes are used. Previous studies with non-diabetic patients found similar results in HbA1c improvement after a 12-week concurrent training program (Virto et al., 2023; Cavero-Redondo et al., 2018). In healthy but overweight young men, a 6-week strength exercise intervention of a single set of 9 exercises performed to failure improved insulin sensitivity, strength, power, and muscle size (Ismail et al., 2019).

The main mechanisms underlying the beneficial effects of exercise are the increase in insulin sensitivity generated in the trained muscle and the induction of glucose uptake in the trained muscle (Sjøberg et al., 2017). In contrast, physical exercise increases capillary density, which increases the expression of glucose transporter protein 4 (GLUT4) in skeletal muscle (Richter & Hargreaves, 2013). This lowers the blood glucose levels, leading to a reduction in HbA1c levels.

Regarding muscle strength, it is interesting to note that the response to eccentric and concentric signaling occurs immediately after strength training; however, muscle mass gain may take several weeks (Franchi et al., 2017; Lum & Barbosa, 2019). Therefore, strength gains at low volumes and high loads during lumbar isometric exercises can be interpreted as a result of neural adaptation, which improves strength independently of muscle hypertrophy (Pearcey et al., 2021). These findings are similar to those of the study by Sperlich et al., in which 6 minutes of exercise was performed daily for 4 weeks (Sperlich et al., 2018). Furthermore, the results obtained were in line with other study that found improvements in lumbar extension torque production with only weekly training for 12 weeks (Carpenter et al., 1991).

The low-volume, high-load strength-training approach improves the strength of untrained and trained individuals (Mattocks et al., 2017; Sperlich et al., 2018). Two strength training approaches (low volume and high load vs. high volume and low load) were compared in untrained youth for 8 weeks. Both groups showed similar improvements in strength; however, the higher-volume group showed greater muscle thickness. These results suggest that higher intensities with lower volumes improve strength, while higher volumes favor strength and muscle hypertrophy

(Mattocks et al., 2017). The minimum resistance dose (low volume and high load +85%) also improved strength in highly strength trained individuals. However, it may become less effective as strength levels improve over time or with the prolonged use of this strategy (Androulakis-Korakakis et al., 2018).

It is important to mention that the workouts were focused on maintaining the maximum possible strength in the 10 seconds of each exercise, which could be considered a limitation of the study. Since the strength was not measured during the workouts, the force applied in real time was not shown, which could be related to the improvement of strength in only one exercise (lumbar extension) instead of in both of them. On the other hand, the sample size is small. In addition, for future research it would be interesting to measure other types of biomarkers to see how testosterone could be used to observe the hormonal development with this type of training.

5. Practical Applications.

Despite the effectiveness of strength training for health, adherence to traditional training strategies is low. Therefore, approaches that require less time and offer significant improvements in muscle strength are needed as a promising strategy to increase adherence.

If low-frequency, low-volume workouts demonstrate such global benefits, time may not prove to be a common excuse for maintaining good health and wellness.

6. Conclusions

In conclusion, the study demonstrated that a short-duration strength training intervention can help improve pain at anatomical points and reduce HbA1c levels, finding trends for improvement in numerous body composition variables. This highlights the significant change in phase angle, a variable with a promising approach in a more accurate and comprehensive study of both body composition and metabolic health. The results are encouraging, and consequently, more studies should be conducted to determine the type of strength training that is most effective in improving overall health.

Strategies are suggested to address ergonomic and postural training as part of university education curricula to prevent and limit musculoskeletal problems in students. There is a lack of randomized clinical studies that control both training and nutrition in active college youths.

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Conflicts of Interest:

The authors declare that they have no conflict of interest.

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