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Original Investigation

Comparison of the effects of isometric and dynamic training on strength and body composition in recreational athletes

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Purpose: The aim of this study was to compare the effectiveness of isometric and dynamic contractions of equal duration in terms of strength development and changes in body composition.
Methods: Recreational strength-trained men (n=20) were divided into two subgroups that performed an isometric and dynamic contraction protocol. Isometric and dynamic contraction protocols were performed 14 times over a 7-week period and preceded and followed by measurements of maximal weight (1RM – one repetition maximum) using the weightlifting method, MVIC (maximal voluntary isometric contraction) measured on an LR2-P upper limb flexor and extensor torques and body composition made using electrical bioimpedance (BIA)
Results: MVIC values increased significantly measured in the angle settings of 30º *P*= .009, 60º *P*= .016, 90º *P*= .048. after isometric training, and after training in dynamic conditions only for the joint angle value of 60º *P*= .016. MVIC differences between the effects of training in isometric conditions and in dynamic conditions, were significant for angles of 90º *P*= .044 and 30º P= .002. The 1RM values did not change significantly after both types of training (pre-post isometric vs dynamic). There were no significant changes in active body mass and body fat of the whole body and segmentally of the upper limbs.
Conclusions: Given the limited scope and limitations of the study, the use of isometric contractions appears to promote an increase in MVIC values in all angular settings (30, 60, 90°), although the greatest differences between static and dynamic training effects were obtained at 30 and 90°. The lack of significant changes in strength (1RM), active body mass and body fat after the application of both types of training, may indicate an inadequate conversion of the selected loading modality to fitness in these characteristics.

Keywords: body composition, contractions under dynamic conditions, isometric tension, maximum force, muscle torques, strength training

Introduction

Muscle strength is considered one of the main human motor abilities. It is most commonly defined as the ability of the neuromuscular system to overcome or resist external resistance [1-3]. The most popular and commonly cited taxonomy of muscle contraction is the relationship between the speed of contraction and the force developed by the working muscle [4,5]. In terms of mechanical properties, two types of muscle activity are distinguished: dynamic (concentric, when the attachments of the active muscle move towards each other; eccentric, when they move away from each other) and isometric - the active muscle does not change its length balancing the value of external forces [6-8].

Increasing muscle strength through the development of muscle mass should include the implementation of contractions of each type, but the responses in terms of neurological and morphological adaptations can be extremely different [1,6,9]. In the context of increasing the functional capacity of the body in the training process, dynamic contractions (concentric and eccentric) are most commonly used [10-12].

In the case of developing maximal strength capabilities, a slight advantage in the effectiveness of eccentric contractions is indicated [5,6,13,14]. It is indicated that the strength values developed during eccentric contractions are relatively greater than concentric contractions by approximately 20-50%, and up to 100% greater than isometric contractions [1,2,15]. Despite the beneficial effect of isometrics on the increase in maximal force values, it is not often the strength training model of choice or preference [16,17].

This is despite the numerous indications that isometric contractions improve maximal strength capabilities [18], increase the force-generating capacity of a specific alignment of bony units with respect to each other [19,20] and positively correlate with the results obtained after dynamic efforts [21-23].

Although with regard to the stimulation of muscular hypertrophy by isometric tensions, the literature is not sufficiently clear and it is pointed out that the effects of isometric training on trained individuals have not yet been sufficiently investigated [16,24], there has recently been an increasing number of publications raising the clarity of this issue [8,10,14]. The problem of comparing the effectiveness of isometric and dynamic contractions of equal duration, in terms of developing muscle strength and possible changes in body composition, is still relevant.

Material

Participants

Recreational strength-trained men (n=20) performed isometric tensions with one upper limb and dynamic contractions with the other limb. Participants had to meet the following eligibility criteria on the recruitment form: male, aged 20-23 years, with at least 2 years of resistance training experience, in good general health and without current injuries. They had a similar lifestyle and exercising at the gym was their only sporting activity. None of the subjects performed heavy physical work outside the training room and did not work overnight. No wellness treatments (massage, sauna, hydrotherapy) were used, and all subjects made relevant declarations that they would not change their diet or use pharmacological support and nutritional supplementation (doping agents, nutrients, vitamins, etc.) during the experiment (Table 1). The subjects did not differ significantly in terms of age, height and weight and training experience, as confirmed by the coefficient of variation values All participants were recruited voluntarily and were informed about the nature of the experiment, with a clear statement of the purpose of the study and possible risks. They were free to withdraw from the study at any time. Written informed consent was obtained from all participants before the start of the study, which was conducted in accordance with the guidelines of the Declaration of Helsinki, and approval was obtained from the University's Research Ethics Committee.

Table 1. Characteristics of the participating in the experiment (mean values ±SD)

Statistical Indicator	Age (years)	Experience (years)	Body height (cm)	Body mass (kg)
Mean	23.90	2	178.30	81.25
Standard deviation	.74	.36	7.93	11.32
Variation Coefficient	.03	.18	.04	.13

Methods

Experimental procedures

The study protocol covered a period of 7 weeks. Measurements of maximal voluntary isometric contraction (MVIC), maximal weight (1 RM – one repetition maximum) in forearm flexion with dumbbells and body composition analysis (BIA), were performed 2 days before the first training session and 2 days after the last. Participants trained twice a week (Tuesday, Thursday), performing a total of 14 sessions. One week before the start of the study, participants were informed about the nature and conduct of the experiment and were divided into two groups of 10 people. The first performed isometric tensions with the left upper limb and dynamic contractions with the right, while the second group did the opposite. The two protocols (isometric and dynamic) were equated in terms of intensity (75-80% 1RM) and duration (60s) [25]. The concentric-eccentric contraction protocol involved performing 6 series of 10 repetitions of forearm flexion at the elbow joint with a dumbbell on a 'Scott's bench' stance, at a rate of 3s up, 3s down (60s). The interval time between series was 3 min. The isometric contraction protocol involved performing six series of tensions of 10 s each, repeated twice, in each of three angular settings of 30°, 60°, 90° (60s) of the forearms in relation to the arm (0° being full extension of the forearm at the elbow joint - the anatomical position). The angular position was determined using the 'Measure' app (Apple, California, USA). The interval time between tension series was also 3 minutes. A team qualified and experienced in research took all measurements across the study group, kept records and, in addition to the participants' natural compliance, supervised them throughout the study.

Measurement of muscle moments (MVIC)

Muscle force moments under static conditions were measured on an upper limb flexor and extensor force moment measuring stand with the symbol LR2-P (JBA Staniak, Warsaw, Poland). To ensure accuracy and reliability of the measurement, the subject's torso was stabilised with a hip roller and seat roller, and the lower leg with an inverted roller. The elbow joint was immobilised with an elbow stabilisation unit. MVIC was measured in an angular position of 30°, 60°, 90° of forearm flexion at the elbow joint. Three tensions lasting 3s in each setting were performed, with 3s of relaxation between them. There was a rest interval of 20s between the triple tensions. The highest force value the participant achieved in the best of the 3 trials was considered as the final measurement result.

Maximum weight measurement (1RM)

After a warm-up consisting of exercises with rubber bands, the maximum load was determined in the exercise 'forearm flexion with dumbbells on Scott's bench' (alternating), using the weightlifting method in the classic variant 'A' [3,5]. Exercises with this method are started with a light weight of approximately 45% 1RM. The use of load progression is generally decreasing and, while at the beginning of the exercise the loads can be increased by 10-20%, by the end (at around maximum load) it is up to 5% at most. Participants performed series with increasing loads. The starting weight was 10 kg and increased by 2 - 0.5 kg until the subject was unable to perform full elbow flexion. The rest time between series was 3 minutes.

Body composition analysis

The Direct Segmental Multi-Frequency BIA (DSM-BIA) with Simultaneous Multi-Frequency Impedance Measurement (SMFIM) was used to perform a comprehensive and segmental analysis of selected body components (body weight, lean body mass, body fat mass, skeletal muscle mass, percentage body fat, right and left arm circumferences) using the InBody 770 body composition analyser from Biospace CO. , LTD., Seul, South Korea. Impedance measurements were taken using 6 different frequencies (1kHz, 5kHz, 50kHz, 250kHz, 500kHz, 1000kHz) of each of 2 body segments (right and left upper limbs). The device takes the actual measurement and does not correct it to population averages as a function of age, gender or body type. As a result, actual tissue component values are obtained with 98% accuracy. Arm lean mass was measured two days before the first training session and two days after the last. Measurements were taken at 8.30 am on an empty stomach (before breakfast), after having had a bowel movement. The subjects were required not to consume fluids from the moment they woke up until the end of the measurement.

Statistical analysis

Repeated Measures ANOVA (Statistica 13, TIBCO Software, Palo Alto, California, USA) was used. The values of static-dynamic force moments in forearm-arm angular settings (30º, 60º, 90º) pre-post ($P < .05$) and for maximum load, body fat and lean body mass static-dynamic, pre-post ($P < .05$) were included as repeated factors. The strength of effect was expressed as: 'insignificant' $0 < \eta^2 \leq .01$; 'small' $.01 < \eta^2 \leq .06$; 'average' $.06 <$

$\eta^2 \leq .14$ and 'large' $\eta^2 > .14$. Differences in the dependent variable between groups were confirmed by the Mauchly sphericity test with Greenhouse-Geisser correlation.

Results

After 7 weeks of experimentation, the mean values of muscle torques (MVIC) after performing training under isometric conditions, indicated significant increases in all angle settings (30° *P*= .009, 60° *P*= .016, 90° *P*= .048). The value of the maximum muscle torques, after performing the workouts under dynamic conditions, increased significantly only for the joint angle of 60° *P*= .018. In terms of maximum weight values (1RM), no significant changes were shown after both isometric and dynamic training (Table 2). MVIC differences between groups (Repeated Measures ANOVA), isometric and dynamic training effects were significant for angles of 90º *P*= .044 and 30º *P*= .002 with a 'small' effect size η2, indicating a small difference between the means (Mauchly's sphericity test - the assumption of sphericity cannot be rejected, so the assumption was not violated $\chi^2 = 5.737$, *P*= .333). The p-values for these angles (90º and 30º) mean that the chance of a type I error (rejection of the correct H0 - null hypothesis) is small. For the 60º angle, the MVIC differences between static/dynamic training effects were non-significant (also with a small difference between means). With regard to the statics/dynamics group differences in (1RM) values, they were also not found to be significant (with a small difference between the means). With regard to the evaluation of changes in body composition (active body mass, adipose tissue), not only was the whole body analysed, but especially the segments that were involved in the exercise, i.e. – the upper limbs. Regarding active body mass, no significant changes were shown for isometric or dynamic tension effects. In the case of isometric training, the difference between the pairs before (M= 24.5, SD= 30.4) and after (M= 26.1, SD= 31.4), t= .5, *P*= .611, was shown to be non-significant through the paired - t test results. For dynamic training, the results of the paired - t test showed that the difference between the pairs before (M= 23.2, SD= 29.1) and after (M= 27.6, SD= 31.5), t= .7, *P*= .512, was also non-significant. After applying the repeated measures ANOVA test, it was also shown that there was a non-significant difference in the dependent variable between the dynamic and isometric tension effects (the assumption of sphericity was violated, $\chi^2 = 20.595$, *P*< .001 - Mauchly's sphericity test, and after applying the Greenhouse-Geisser correlation ε= .633, confirmation of non-significance was obtained).

Table 2. Values of maximum muscle torques for angles of 90º, 60º, 30º and maximum weight (1RM) before and after training in static and dynamic conditions (±SD)

Torque	Before experiment	After experiment	T	*P*
Maximum muscle torques				
90 º				
Statics [Nm]	91.78 ±14.00	106.58± 17.14	2.115	**.048**
Dynamics [Nm]	90.35 ± 14.95	104.59 ± 23.63	1.610	.124
60º				
Statics [Nm]	92.02 ±14.61	109.43 ± 14.67	2.659	**.016**
Dynamics [Nm]	92.2 ± 13.6	110.23 ± 17.35	2.586	**.018**
30º				
Statics [Nm]	87.27 ± 16.76	113.98 ± 23.53	2.924	**.009**
Dynamics [Nm]	93.07 ± 19.05	113.57 ± 35.12	1.623	.122
Maximum weight (1RM)				
Statics [kg]	22.85 ±3.32	25.55 ±2.75	1.981	.063
Dynamics [kg]	22.80 ±5.24	25.75 ±3.34	1.501	.151

T– T statistic test; P– p value

With regard to body fat content, no significant changes were found for isometric or dynamic tension effects. For those using isometric tensions, the paired - t test results showed that there was a non-significant, very small difference between before (M= 1.7, SD= 2.5) and after (M= 1.6, SD= 1.9), t= .6, *P*= .577. For dynamic training, the results of the paired - t test also showed that there was a non-significant small difference between before (M= 2.2, SD= 2.4) and after (M= 2.9, SD= 3.5), t= 1.3, P= .201. Due to the lack of significant differences between the 'before' and 'after' test results for isometric as well as dynamic tension effects, the comparison between the two was abandoned.

Discussion

In terms of the training cycle needed to produce positive effects, it is assumed that significant changes in strength occur after 8-12 weeks [12,24], although significant strength gains have also been reported over shorter time periods of 4-7 weeks [5,26]. The duration of our experiment therefore does not deviate from the aforementioned indications, which creates favorable conditions for comparisons of the effects obtained in procedural terms.

As the authors on contraction effectiveness point out, the value of strength gains can vary depending on the type and duration of the contractions, the length of the cycle in which they are applied, the intensity of the contractions, the number of contractions in a series, the number of series, the rest time between series, the joint angle and other training estimators.

Table 3. Significance of differences and effect size η2 of maximuwm muscle torques for 90º, 60º, 30º angles and maximum weight (1RM) between static/dynamic training effects

	Effect size η^2	F	*P*
		90º	
differences between static/dynamic training effects	.033	2.869	**.044**
		60º	
	.023	.836	.479
		30º	
	.012	2.663	**.002**
		Maximum weight (1RM)	
differences between static/dynamic training effects	.017	1.803	.085

Note: Effect eta squared (η^2); F– F statistic test; *P*– p value

Regarding joint angle, as indicated by Kruszewski [26], after the application of isometric tensions, the greatest increase in force values is observed within a specific angular setting and up to 15° from it. These indications seem to be confirmed by Lum and Barbosa [16], who indicate an increase in strength within the trained angular setting, although other authors point out that the spectrum of influence can reach up to 20-50° [26,28,29]. They also indicate that isometric tensions in a stretched muscle position (obtuse angle) result in greater gains in strength levels than in other angular settings [16,20,29].

Our results indicate that training with isometric tensions results in a significant increase in the value of force (MVIC) measured at all joint angles tested 30°,60°,90°. When dynamic training was applied, significant strength gains (MVIC) were only found at joint angle values of 60°, although significant intergroup differences (isometrics versus dynamic) occurred only at angle settings of 90° and 30°. This may indicate that isometric training is more effective than dynamic training in terms of being able to improve the strength effects of the muscle in different ranges of action, defined by non-uniform joint angle values (acute, right, and obtuse angles). In addition, our results confirm the effect of obtaining the highest force values at an angular setting of 30° (acute angle), which stands in opposition to the views indicated above. The reasons for this should therefore be seen in the differences in both joint angle values and other training protocol parameters, which probably include contraction intensity.

The dependence of force gain values on other angular settings and the intensity of isometric contractions has also been investigated by many authors [5,30,31]. In terms of these relationships, they indicate that isometric contractions of submaximal intensity of at least 75% (1RM) and lasting at least 5 s result in greater strength gains than shorter and more intense or longer contractions of lower intensity. Given the above, our isometric contraction protocol appears to meet these conditions, but the experimental results are not compatible with those previously obtained by Thepaut-Mathieu et al [31], who conducted a study using 5 s isometric contractions at joint angles of 60°, 100°, 155°. They observed the largest increase in MVIC values at 155° (39%), followed by 100° (27%) and the smallest at 60° (17%).

The inconsistency in the effects of this experiment and ours may be due to differences in the training intensities and frequencies used, although it should be noted that effects similar to those obtained by us are more commonly found in publications on similar topics. Reference can be made to the former studies by Rasch and Pierson [32], in which no significant differences were found in MVIC force values) measured in multiple joint angle settings and more recent studies where differences were found in only some of its values (20°- 50°) [28,33].

Effects similar to those obtained in our experiment are further indicated by Kubo et al. and Lee et al [19,34], which seems to confirm the validity of using acute angles to obtain significant strength gains (MVIC).

When comparing the effectiveness of isometric and dynamic contractions in terms of the ability to obtain muscle strength expressed as MVIC, we showed that the greatest significant differences occur at a joint angle value of 30°. This result may indicate that isometric training is more effective than dynamic training, which is not always clearly confirmed in the literature (Urlich et al [35]. However, most studies seem to confirm our results due to the achieved (MVIC), although the differences are small or insignificant if the duration and intensity of the loads are similar [24,32].

With regard to the strength value measured by the dynamic strength test (1RM), it should be pointed out that it did not increase significantly after the application of both types of contraction (training). Regarding the research protocol, it should be noted that a taxonomy of loads was adopted in line with the indications of the literature, which describes strength training methods in detail [5,36,37]. Despite the methodological differences in the application of training loads found in various publications [34,36], it appears that the experimental design used in the protocol, falls within the methodological indications recommended by authors dealing with this subject [38,39,40].

Confirmation of the validity of the training protocol used is also found in publications indicating that slight deviations from methodological patterns are often expedient and can be just as effective as strict adherence to them [3,15,34].

As a recommendation for the future, it is worth noting that, in order to more fully illustrate the differences between the effectiveness of isometric and dynamic contractions, it would be necessary to measure maximum muscle torques also under dynamic conditions using, for example, inertial dynamometers, something that was lacking in our experiment. In order to better establish a base for more general inference, it would also be

advisable to increase the value of training stimuli in terms of their volume, intensity and frequency of training.
In terms of the aim of the experiment, which was also to compare the effectiveness of using the two types of contraction as manifestations of building strength and muscle mass simultaneously, changes in the participants' body composition were also monitored.
However, body composition measurements using the electrical bioimpedance (BIA) method after the application of both types of contraction showed no significant changes in active body mass and upper limb fat content values. In this case, it should be concluded that the training protocol applied did not promote the development of muscle mass or the reduction of body fat. In terms of the applied volume and intensity of loads and training frequency, it was unlikely to achieve the aforementioned changes, which is also indicated in the literature [27,41-43]. Nevertheless, the use of other methods of body composition testing - ultrasonography, MRI, biopsy, CT or densitometry, cited by researchers as more accurate, reliable and credible - can be recommended as an indication for further research.

Practical application

The results provide insight into the complex interactions between the training types used and may provide useful guidance on the use of static and dynamic contractions to enhance the effectiveness of strength training. It is strongly recommended that future studies include a larger sample size and a higher training frequency, which would allow determining possible differences in the effects of these two types of muscle activity also on changes in body composition.

Conclusions

1. Isometric training with the loading parameters used in our study promotes an increase in MVIC values in 30, 60, 90° angular settings, illustrating its potential for developing muscle strength.
2. Significantly greatest MVIC differences between static and dynamic training effects were noted in the 30° and 90° forearm to shoulder angle settings, which may indicate increased strength development in a position of significant muscle shortening as well as at mid-length.
3. The lack of significant changes in strength values after dynamic training with the load parameters used in our study, as measured by (1RM), may indicate in this case that it is less effective compared to isometric training.
4. The reason for the lack of significant changes in body composition after both types of training, should be attributed to the inadequate conversion of the selected load modality to fitness in terms of active body mass development and fat reduction.

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Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Ethical Committee approval

SKE01 – 38/2023 Senate Committee on Ethics of Scientific Research Józef Piłsudski University of Physical Education in Warsaw.

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Topic

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Conflicts of interest

The authors have no conflicts of interest to declare.

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Author-s contribution

Conceptualization, M.K., R.T., K.Z. and A.K.; methodology, M.K. , R.T. and A.K.; software, M.K. and A.K.; validation, M.K. and A.K.; formal analysis, M.K.; investigation, M.K. and A.K.; resources, M.K and A.K.; data curation, K.Z. and R.T.; writing—original draft preparation, M.K., A.K. and K.Z.; writing—review and editing, M.K., A.K. and R.T.; visualization, M.K., K.Z. and A.K.; supervision, M.K. and A.K.; project administration, A.K. All authors have read and agreed to the published version of the manuscript.

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