International Journal of
Sports Science
& Coaching

Original research

International Journal of Sports Science
& Coaching
0(0) 1–9

DOI: 10.1177/1747954117746457
journals.sagepub.com/home/spo
SAGE

The Hatfield-system versus the weekly undulating periodised resistance training in trained males

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Abstract

The purpose of this study was to compare training adaptations attained during six weeks of using the Hatfield-system and six weeks of the weekly undulating periodisation strength training. Twenty-six recreationally strength trained men were randomly assigned to either a Hatfield-system group ($n = 13$; age $= 26.8 \pm 7.2$ years) or a weekly undulating periodisation group ($n = 13$; age $= 29.2 \pm 9.0$ years). Anthropometric measures and strength testing were performed before (PRE) and after six weeks (POST) of training. To subjectively quantify the individual's perception of the physical demands of the intensity of resistance training, a category-ratio scale (CR10) was used by the subjects after each training session. The participants of both groups trained twice a week for six weeks. The Hatfield-system and weekly undulating periodisation programmes used the same exercises, the same total training volume and the same total intensity in these six weeks. The difference between the two programmes was in the distribution within each training phase. The Hatfield-system and weekly undulating periodisation groups trained using a periodised strength programme with all programme variables controlled (e.g. volume and intensity). The Hatfield-system group used a linear not varying intensity, whereas the weekly undulating periodisation group had a varied intensity. The results show that both the Hatfield-system and weekly undulating periodisation groups made significant ($p \leq 0.05$) increases in strength and power. The results of this study indicate that the Hatfield-system model is no more effective than the weekly undulating periodisation model for increasing strength, power and muscle size.

Keywords

Hatfield-system, periodisation, strength training, weekly undulating

Introduction

To achieve top results in high-performance sports, an appropriate periodisation of training is indispensable. Periodisation is a training scheme where exactly planned variations in training variables (e.g. number of sets and repetitions, exercise order, load and rest) are manipulated at regular time intervals in an attempt to generate optimal gains; for example, in strength, power, speed, endurance, and so on.[1–6] At the same time, performance stagnation such as adaptation plateaus and overtraining states should be avoided.[3,7,8] The training process is based on an overload principle and it attempts to maximise the use of physical stress and recovery time by manipulating volume and intensity to facilitate important neuromuscular adaptations.[9–11]

Poliquin[12] suggested undulating periodisation and claimed that other training programmes lose their effectiveness after just two weeks due to the rapid adaptation of the muscles to stress, which happens because the neuromuscular system makes a fast adaptation to the training stimulus. Neuromuscular adaptations to manage training load performance is only possible through a high-frequency scheme that alternates the

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load norms, such as the intensity, frequency and scope.[3,6,9,10,13–19] The undulating periodisation relies on irregular manipulation of volume and intensity across the training cycle and it includes short periods of high-volume training alternated with short periods of high-intensity training within one week.[8,9,16] This allows the control of different training goals, such as hypertrophy, maximal strength, power endurance or explosive power. Thereby, the undulating periodisation may have various advantages in terms of better compatibility in the training, planning and implementation, as well as a more flexible individualisation.[14,16,20]

Hatfield[15] also followed this conceptual model in the form of a 'holistic training model', which is based on the specific adaptation to imposed demand (SAID) principle. Hatfield suggested that different components of a muscle cell are also able to respond and adapt to various stimuli. These stimuli are generated by high and low number of reps, in different speeds (fast and slow execution) and with different repeat intervals. Hatfield tried to process as many cell elements as possible in one training session in order to stimulate all of these components. In this regard, high reps (i.e. 20–25) are intended to improve muscular endurance by increasing the number of mitochondria in muscle cells and generating new capillaries. Moderate reps are thought to enhance cell plasma and achieve muscle growth. Low reps (i.e. 4–6) with a heavy load should stimulate the myofibrils of muscle fibres and improve maximum force.[15]

In practice, and especially in team sports or in sports that are mostly multiple periodised (e.g. tennis, ball games, etc.), there are often problems with regard to the practical implementation of a targeted strength training due to the weekly sport-specific loads. Because many coaches focus primarily on tactics and technique, the time resources to improve strength abilities are often limited.[21] Assuming that the Hatfield-system (HAT) is capable of achieving the same or even better effects as the weekly undulating periodisation (WUP), the training goal to improve strength endurance, maximal strength or hypertrophy would be achievable without the usually necessary specific and time-consuming transition phase. The purpose of this study was to compare the training adaptations after six weeks in the HAT and WUP models, thus adding to the similar publications of Bartolmei et al.[22] and Buford et al.[10]

Method

Experimental approach to the problem

A total of 26 men with strength training experience served as subjects. A total of 13 men were assigned to a HAT group and the remaining 13 comprised the WUP group. The first group performed a six-week HAT training programme, including two mesocycles with a constant training volume throughout each mesocycle. The second group followed a six-week WUP, also including two mesocycles composed of varied training volume and intensity within each mesocycle. The participants were assessed for leg strength, power, strength endurance and anthropometry before and after the training programme. The strength training was performed as machine-loaded exercise movements (e.g. leg press, leg extension, or leg curl).

Subjects

A total of 36 healthy and resistance trained men were recruited from the university setting via an informational lecture and information brochures in three different gyms and in three different cities. Prior to the start of the study, the participants received a group orientation consisting of a presentation outlining the reasons and goals of the training. The participants were informed about the possible risks and benefits of periodised strength training and they were given the opportunity to ask questions. After the presentation, the participants read an information letter, completed a health screening form and a physical activity readiness questionnaire, and they signed an informed consent form. Participants were excluded from participation if they had a known history of metabolic, cardiovascular, respiratory or musculoskeletal system disorders. The investigation was approved through the Research Ethics Board University of the University of Innsbruck for the use of human subjects. Finally, 13 men were randomly assigned to the HAT group (age $= 26.8 \pm 7.2$ years, body height $= 180.7 \pm 5.9$ cm, body mass $= 84.8 \pm 9.9$ kg, BMI $= 26.0 \pm 3.3$ kg/m^2; relative power values on leg press at baseline (power index: 1RM-benchpress/body mass) $= 3.9 \pm 0.9$) and 13 men were assigned to the WUP group (age $= 29.2 \pm 9.0$ years, body height $= 173.2 \pm 9.3$ cm, body mass $= 78.4 \pm 10.4$ kg, BMI $= 24.7 \pm 2.6$ kg/m^2; relative power values on leg press at baseline (power index: 1RM-benchpress/body mass) $= 3.8 \pm 1.1$). All of the participants had previous resistance training experience (≥ 1 year (range 1–10 years)) using free weight and machine resistance before the start of the study.

Procedures

Testing sessions. Before initiating the six week training programme, the participants followed a one week familiarisation programme in which the same tests were organised in circuits and performed to find the exact techniques of execution and loads. Subjects were assessed before (pre-test: PRE) and after (post-test: POST) the six week training programme. There were two forms of testing carried out on two days: On the first day the anthropometric assessments (body mass, height, circumference of thigh and skinfolds) were performed at the beginning of each testing session and after the first part of the strength assessments (SJ: squat jump; CMJ: counter movement jump; ILT: isometric leg extension strength test). The second day (next day) included the second part of the strength assessments (1RM: 1 repetition maximum, RM40%: repetition maximum with 40% of the 1RM).

Anthropometric assessments. Anthropometric assessments consisted of body composition testing using a skinfold Lange calliper (Beta Technology Inc., United States) and thigh circumference measurements were made using a standard anthropometric measuring tape. The circumference of the right thigh and the anterior thigh skinfold were measured when the subjects lay on a therapists table, with their leg flexed (90°) and the measurements were taken at the midpoint of the thigh (i.e. 50% of the distance between the greater trochanter and lateral epicondyle of the femur).

The muscle cross sectional area (CSA) was calculated with the Housh multiple regression (HMR), which was developed by Housh et al.,[20] and the following equation was used:

$$\mathrm{CSA}\left(\mathrm{cm}^2\right) = (4.68 \times \text{thigh circumference}) - 0.64 \times \text{anterior thigh skinfold in mm}) - 22.69$$

Body height was measured to the nearest of 0.1 cm by using a portable stadiometer Seca 220 (Seca, Germany). Body mass was determined to the nearest of 0.1 kg using a portable scale TBF-531 (Tanita, Sindelfingen, Germany). All the anthropometric measurements were performed by the same trained investigators. The body mass index (BMI) was calculated by dividing the body mass (kg) by the square of the height (in m). The intraclass coefficient (ICC) for body mass was 0.955 (SEM: 2.1 kg), for BMI 0.987 (SEM: 0.6 kg/m^2) and for the circumference of the right thigh 0.961 (SEM 0.50 cm). The ICC for CSA was 0.960 (SEM: 1.55 cm^2).

Testing protocol. The PRE was performed three days after a pretest, which included the same tests in the same order. The whole test battery was carried out again three days after the last training session because an adequate regeneration period of 72 h is necessary to assure an optimally recovered neural stimulus transfer and transmission ability for maximal stimulus intensities.[5,23] All of the tests were realised in the order described below after a standardised warm-up. The best tests were used for statistical comparison. Two test batteries were created:

Strength and power measures. Strength testing consisted of a maximal isometric leg extension test (ILT), 1RM test, a power endurance test with 40% of the 1RM in the leg press, body weight countermovement jump (CMJ) and body weight squat jump (SJ).

Isometric leg extension strength test. The warm up consisted of 10 min of submaximal cycling on an ergometer. This test was accomplished on a seated unilateral leg press, which is a self-developed test device that measures maximal isometric leg extension strength in a closed kinetic chain. Force was measured by a load cell (Hottinger Baldwin, Darmstadt, Germany) under the foot plate and the signals were processed with a Spider 8 (Hottinger Baldwin, Germany), which was connected to a computer. All the collected data were displayed and analysed by LabView software (National Instruments Corp., Austin, TX). The subjects performed three isometric leg extensions with each leg, with the knee flexed at 85° and at 120° (180° full extension). The exact angles were set with a goniometer. The landmarks of greater trochanter, lateral intercondylar notch and lateral malleolus were used to determine knee angle. The inclination of the footplate was changed when the knee angle was at 85° (more steep) and at 110° (more flat). Both legs (right, left) were tested. The highest force for each leg was recorded. An internal analysis identified the ICCs of 0.832 (ILT 120° right leg) (SEM: 151 N), of 0.806 (ILT 120° left leg) (SEM: 205 N), of 0.806 (ILT 85° right leg) (SEM: 42.5 N) and of 0.883 (ILT 85° left leg) (SEM: 44 N).

CMJs and SJs. After specific warming up, the subjects descended with hands on hips into a squat at the height where a 110° knee angle was reached. The exact angles were set with a goniometer which was adjusted to 110°. The landmarks of greater trochanter, lateral intercondylar notch and lateral malleolus were used to determine knee angle. Afterwards the subjects jumped without a counter movement. All the subjects completed three SJ. After a rest of 5 min, three CMJ with maximum explosive intent with hands on hips were performed to assess lower-body power. Jumping height was estimated by using a force plate (Kistler Holding AG, Winterthur, Suisse) with a sample rate of 500 Hz. The highest jump height was calculated by the impulse-momentum method with LabView software (National Instruments Corp., Austin, TX). Each testing session was performed without shoes at the same time of the day and was followed the same number of rest days from the last training workout. The ICC for CMJ was 0.917 (SEM: 1.09 cm) and for SJ 0.885 (SEM: 1.30 cm).

1RM test and power endurance test with 40% of the 1RM on the leg press. The specific warm up consisted of 10 min of submaximal cycling on an ergometer and two to three sets of moderate (about 60% of 1RM) loaded leg pressing, with a maximum of six repetitions each. Dynamic maximum strength was measured using the 1RM on the leg press model type pure strength secondary feature (Technogym, Gambettola, Italy). The maximal load was determined in a series of 1RMs, the loads between the attempts were increased by 2.5 and 5. There was a least 5 min rest between attempts. In the leg press, the load was lowered from 170° extension knee joint angle to a knee joint angle of 90°. The lowering of the 1RM tests was monitored using a goniometer attached to a knee brace (Rescall, Imst, Austria). The subjects had the knee brace on their right knee to supervise the movement range in the knee joint. At the starting position (with both legs on the plate), a trigger was set. Determination of 1RM was achieved within a maximum of three trials, the subjects went to failure. The ICC for 1RM was 0.955 (SEM: 13.62 kg). After a rest of 10 min the subjects had to absolve the power endurance test with 40% of the 1RM in the same leg press with the same movement range used for the 1RM test. The ICC for RM with 40% was 0.720 (SEM: 2.2 reps). The criterion for a successful attempt in both tests was a trial in which the legs were completely moving (starting and end position) the range of the brace. Attempts also failed when the subjects rounded their back.

Psychophysical assessment. The feelings of effort, strain, discomfort and/or fatigue experienced during resistance training were measured by the rating of perceived exertion (RPE), which is normally used to subjectively quantify an individual's perception of the physical demands of an activity and also to quantify the intensity of resistance training.[15,24,25] All the subjects used the revised scale including a category-ratio scale (CR10) with rating values (rv) from 0 (nothing at all) to 10 (extremely strong).[18] The subjects had to fill in their perceived exertion after each workout in their workout dairy over the whole six weeks. This RPE tool is not influenced by age.[26]

Resistance training protocols

At the beginning of the training both groups were properly instructed in the implementation of the exercises and the handling of the machines to make sure that the implementation matches the specific distribution by well-educated trainers (all trainers completed a national coach education). Furthermore, support was also ensured by these professionals during the whole six week training period. The resistance training was performed by machine-loaded exercise movements (leg press, leg extension, leg curl) using identical devices from Technogym (Technogym, Gambettola, Italy) in three different gyms. Both groups had to absolve six sets on the leg extension machine, six sets on the leg curl machine and at least six sets on the leg press, twice a week (Monday and Friday) and always in this order to ensure that enough regeneration time was available. The basic control of the intensity levels was carried out by the range of numbers of the repetition in one set (goal repetitions).[13]

The HAT programme consisted of two three-week mesocycles. The workload distribution of the HAT programme for one workout has the following structure and the following characteristics. Set 1 + 2 (reps: 4–6, weight: maximum, method: explosively (concentric: 0.75–1.0 s), with pausing between each repetition (maximum: 2 s), rest of set: 5 min) set 3 + 4 (reps: 12–15, weight: maximum, method: moderate speed (concentric: 1–1.5 s), with a relaxation pause between each repetition (maximum: 2 s, rest of set: 4 min). Set 5 + 6 (reps: 20–25, method: perform each repetition in a slow (concentric: 1.5–2 s), sustained fashion (i.e. keep continuous tension on the muscle throughout the concentric and eccentric phases of the movement). No rest pauses through the entire set, Rest of set: 3 min). To activate the FT (fast twitch) fibres, the repetitions should be done quickly, correctly and explosively. This takes into Hatfield into account through various forms of repetition implementation:[15]

1. explosives with short breaks between reps,
2. moderate with short breaks between reps, and
3. slowly without a break and with constant tension.

The WUP programme consisted of two three-week mesocycles. During each mesocycle, training load progressed from a low volume and high intensity toward a high volume and low intensity. The first week of each mesocycle focused on maximal strength and the participants performed a low number of repetitions using heavy loads. The second week of each mesocycle focused on muscle hypertrophy. During the third week of training, the total training volume focused on strength endurance and the participants performed a high number of repetitions using easy loads. The WUD programme includes the same intensity and volumes as HAT but it changed weekly. The speed of the identical exercises was different to the HAT. The speed for each repetition was performed with 2 s for the eccentric and 1 s for the concentric phase without breaks between and at the start. The training values for one workout for one exercise of WUD programme for each week are reported in Table 1.

Strength training was carried out twice a week for six weeks. The training volume and training intensity were the same for both groups (Figure 1).

Table 1. Training values for the WUP strength training program for each exercise.

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Load dynamics	6 × 4–6 RM	6 × 12–15 RM	6 × 20–25 RM	6 × 4–6 RM	6 × 12–15 RM	6 × 20–25 RM
Rest of set (min)	5	4	3	5	4	3

WUP: weekly undulating periodisation; RM: repetition maximum.

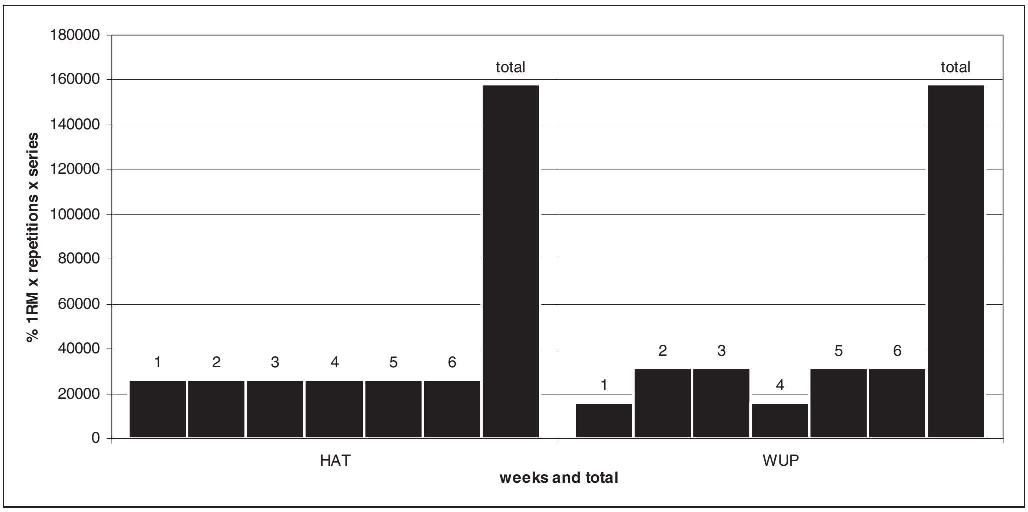

Figure 1. Training volume (% of 1RM × sets × repetitions) and intensity (% of 1RM) during six weeks provided in both groups (HAT and WUP).
HAT: Hatfield-system; WUP: weekly undulating periodisation; RM: repetition maximum.

Both groups kept a diary of their nutrition and their workout. Based on studies using nitrogen balance methodology, the daily protein intake recommendation for athletes engaged in endurance and resistance activities is 1.2 to 1.7 g/kg body mass.[27] The participants were informed that they had to realise an individual protein supply of at least 1.5 g/kg body mass per day.

Statistical analyses

The best out of three trials of 1RM, ILT, CMJ and SJ was recorded and analysed. First, the Shapiro–Wilk normality test was used to quantify the deviation of the actual data from a Gaussian distribution. Homogeneity of variance was calculated with the Levene test. Test requirements were fulfilled at a significance level of $p \leq 0.05$. A 2 × 2 (group × time) mixed factor ANOVA was used to analyse within group and interaction effects. All data analyses were conducted with IBM SPSS Statistics 21.

Results

The whole training and testing procedure was completed as planned. All the subjects performed their training regularly without any adverse effects. Diaries of their workout and nutrition have been completed by all the participants. There were no drop outs.

Anthropometry

Within-group changes. The ICC indicated a mean of 0.974 for test–retest reliability with regard to body mass, BMI, thigh circumference measurements and CSA. The anthropometric data of HAT and WUP groups are depicted in Table 2. Both the HAT and WUP groups showed only small changes (relative percentage) in anthropometric measurements (PRE to POST). A significant main effect ($p \leq 0.05$) of time on CSA was found in the HAT group ($p = 0.019$, HAT = 1.9%) but not in the WUP group ($p = 0.075$, WUP = 1.6%). No other significant main effects of time were seen on the other anthropometric parameters.

Between-group changes. There were no significant differences between groups with regard to the anthropometric characteristics (PRE to POST) (Table 2).

Performance assessments

Within-group changes. The ICC indicated a mean of 0.841 for test–retest reliability on 1RM, RM 40%, SJ,

Table 2. Comparison of anthropometric measurements of both groups.

Anthropometric assessments		HAT (mean ± SD) N = 13	WUP (mean ± SD) N = 13	Within group effects HAT	WUP	Interaction effects
Body mass (kg)	PRE POST	84.7 ± 9.9 85.8 ± 10.4	78.3 ± 10.3 79.2 ± 10.2	$p = 0.059$	$p = 0.093$	$p = 0.789$ $F = 0.73$ $\eta^2 = 0.003$
BMI (kg/m^2)	PRE POST	26.8 ± 3.3 26.3 ± 3.4	24.7 ± 2.6 24.9 ± 3.1	$p = 0.060$	$p = 0.080$	$p = 0.759$ $F = 0.960$ $\eta^2 = 0.004$
Right thigh circumference measurements (cm)	PRE POST	57.2 ± 4.4 57.7 ± 4.7	53.9 ± 4.2 54.5 ± 5.6	$p = 0.165$	$p = 0.111$	$p = 0.940$ $F = 0.006$ $\eta^2 = 0.000$
Thigh CSA (cm^2)	PRE POST	235.3 ± 19.3 239.7 ± 20.3	222.9 ± 18,2 226.3 ± 16.8	$p = 0.019$	$p = 0.075$	$p = 0.638$ $F = 0.254$ $\eta^2 = 0.018$

HAT: Hatfield-system; WUP: weekly undulating periodisation; PRE: initial test; POST: post-test; BMI: body mass index; CSA: muscle cross sectional area.

CMJ and ILT. A significant main effect of time ($p \le 0.05$) was found for 1RM (HAT: $p = 0.001$, WUP: $p = 0.000$), RM 40% (HAT: $p = 0.001$, WUP: $p = 0.000$), SJ (HAT: $p = 0.064$, WUP: $p = 0.016$), CMJ (HAT: $p = 0.017$, WUP: $p = 0.017$), ILT right leg 85° (HAT: $p = 0.015$, WUP: $p = 0.009$), ILT right leg 120° (HAT: $p = 0.000$, WUP: $p = 0.000$), ILT left leg 120° (HAT: $p = 0.030$, WUP: $p = 0.000$). No significant main effect ($p \le 0.05$) was found for time in ILT left leg 85° (HAT: $p = 0.106$, WUP: $p = 0.055$).

Between-group changes. No significant ($p \le 0.05$) differences in the different strength and power assessments were noted at baseline among any of the groups (HAT and WUP) (Table 3).

Psychophysical assessment. The RPE indicated a mean of 7.7 in the HAT group and a mean of 6.4 in the WUP. There is a mean difference of 1.3 in the rating of REP. This showed that the HAT group perceived that their programme was more exhausting than the WUP group.

Discussion

The purpose of this study was to determine whether HAT periodised strength training would enable greater strength gains (dynamic maximum strength, static maximum strength, power endurance and explosive power) over six weeks of training in males with previous weight-lifting experience than WUP training. The findings indicate that both HAT and WUP programmes were highly effective in improving strength but changes did not differ between groups. Comparing the current study with other periodised strength training studies is not straightforward because these studies usually only represent comparisons of traditional linear periodisation with an undulating periodisation.[28,29] Another problem arises from the use of different subjects (trained/experienced or not).[30] The period for this study was six weeks, and it was done with experienced subjects who already had a high level of training. All subjects were used to training with the specific exercise machines in this study. Despite the relatively short intervention period, high performance gains were demonstrated that have been achieved only over long periods in most studies.[14]

Both groups performed a high volume of training (18 sets for the legs, distributed (six sets each) over three exercises) in this study because strength gains, muscular adaptations, as well as better sustainability of effects are directly related. At the same time, it was ensured that both groups (HAT and WUP) executed total and equal intensities for the entire workout period (Figure 1). No previous study is known to the authors where such a high volume of training has been used. However, the fact remains that a strategy of higher volume training (exercises, sets) per workout, even for a short period (e.g. 6 weeks), will cause higher maximum strength values in the lower extremities.[31,32] This was confirmed in the present study. Krieger[25] also tried to determine whether multiple sets per exercise are associated with greater muscle hypertrophy than a single set per exercise in a resistance training programme with experienced subjects (>6 months). Multiple sets per exercise were associated with significantly greater effect sizes. In his meta-analysis the mean effect size for a single set per exercise was 0.25, whereas the mean effect size for multiple sets was 0.35. Thus, multiple sets were associated with 40% greater hypertrophy-related effect sizes than a single set.

Table 3. Results of strength and power measurments.

Strength assessments		HAT (mean ± SD) $N = 13$	WUP (mean ± SD) $N = 13$	Within group effects HAT	Within group effects WUP	Interaction effects
1 RM (kg)	PRE POST	335.5 ± 101.6 398.4 ± 117.9	300.9 ± 82.0 350.0 ± 98.9	$p = 0.001$	$p = 0.000$	$p = 0.320$ $F = 1.033$ $\eta^2 = 0.041$
RM 40% (Reps)	PRE POST	37.8 ± 8.2 45.0 ± 9.7	33.7 ± 5.0 41.5 ± 9.4	$p = 0.001$	$p = 0.000$	$p = 0.809$ $F = 0.059$ $\eta^2 = 0.002$
SJ (cm)	PRE POST	28.7 ± 5.2 30.7 ± 4.3	26.3 ± 5.9 28.9 ± 5.8	$p = 0.064$	$p = 0.016$	$p = 0.624$ $F = 0.246$ $\eta^2 = 0.010$
CMJ (cm)	PRE POST	35.7 ± 7.2 38.4 ± 5.5	34.1 ± 6.0 35.5 ± 5.3	$p = 0.017$	$p = 0.017$	$p = 0.233$ $F = 1.525$ $\eta^2 = 0.060$
ILT right leg 85° (N)	PRE POST	1103.2 ± 230.9 1200.8 ± 217.5	961.5 ± 202.6 1067.8 ± 266.5	$p = 0.015$	$p = 0.009$	$p = 0.758$ $p = 0.858$ $F = 0.33$ $\eta^2 = 0.001$
ILT left leg 85° (N)	PRE POST	1040 ± 231.6 1097.9 ± 234.9	905.9 ± 206.3 992.5 ± 264.2	p = 0.106	p = 0.055	$p = 0.590$ $F = 0.298$ $\eta^2 = 0.012$
ILT right leg 120° (N)	PRE POST	2443.4 ± 1076.2 2932.0 ± 1069.9	1965.7 ± 607.3 2739.1 ± 898.0	$p = 0.000$	$p = 0.000$	$p = 0.071$ $F = 3.56$ $\eta^2 = 0.129$
ILT left leg 120° (N)	PRE POST	2307.1 ± 1023.2 2688.7 ± 1017.8	1900.1 ± 701.4 2598.1 ± 869.9	$p = 0.030$	$p = 0.000$	$p = 0.136$ $F = 2.38$ $\eta^2 = 0.09$

HAT: Hatfield-system; WUP: weekly undulating periodisation; PRE: initial test; POST: post-test; RM: repetition maximum; SJ: squat jump; CMJ: counter movement jump; ILT: isometric leg extension strength test.

Similar results were found in the improvement of power endurance. Even here, there are similarities to existing studies.[8,33] They also usually demonstrated significant improvements within groups but almost never between groups. Looking at the results of this study in relation to the influence of the moving speed in the concentric and eccentric phase, parallels to the findings of Morrissey et al.[34] can be seen. The results showed that studies in which the identical exercise was performed at different speeds have not shown an advantage to a particular exercise movement speed. A similar study by Palmieri[35] examined effects of resistance training on the maximal strength in the squat and the maximum vertical jump height as dependent variables. The first group led the concentric phase of training exercises in a maximum of 0.75 s, while the second group within 2 s. The third group trained with the slow-motion version in the concentric phase in the first six weeks and in the last four weeks they trained with the fast movement execution. The power in the vertical jump execution significantly improved in all three groups, although there were no significant differences between the groups. Young and Bilby[36] investigated the influence of the speed of movement execution in the squat. Two groups that trained with different versions of speed at the squat were compared. The 1RM in squat, the vertical jumping ability, the maximum isometric strength in the squat and the circumference of the thigh were measured. Both groups improved significantly in all examined variables, but there were no significant differences between the two groups.

The authors have assumed that the different methods of execution (e.g. movement speed, rests between the reps and daily content) could make it possible to produce different results in the anthropometric, performance and psychophysical assessments. The results confirm that a combination of high- and low-intensity regimens is effective for optimizing the strength adaptation of muscle in a periodised training programme.[37] The homogeneity of the subjects, the similarity of the programmes and the guarantee of the same total training volumes and intensities should have been decisive for the significant growth in the group, on the one hand, and for the lack of differences between groups, on the other hand. The large improvements that were demonstrated in a relatively short time (6 weeks) in already strength trained subjects are remarkable and it would be interesting to show whether a further increase in strength could be achievable through an additional mesocycle (3 weeks) or if the performance changes have already plateaued. It would also be interesting to see whether differences in the effects between groups would occur during continuation of HAT and WUP training.

In conclusion, it has been demonstrated that six weeks of periodised weight training improved strength in well-trained subjects; however, there was no difference in strength gains between HAT and WUP. As the application of the HAT resulted in very similar effects as the WUP, the training goal to improve strength endurance, maximal strength or hypertrophy would be achievable without the usually necessary specific and time-consuming transition phase.

Practical applications

Subjects in both groups showed significant increases in all types of strength despite the fact that they were already experienced in strength training. The most impressive advantages of both periodisation models are the large improvements within a short period of time (6 weeks) without remarkable changes in body mass. This could be a reason to use these programmes for optimal gain in maximal strength (relative strength) for all type of sports, where the capacity should increase but the body mass should not increase (e.g. boxing, tennis, or wrestling). The use of both models is very effective but similar. The decision to use HAT or WUP depends on the type of athlete because the basic principle of both periodisation models is a very high volume of training. It has been found that there is a somewhat higher level of exertion with HAT. If someone likes the structure of the programme (all in one), then he or she should take HAT. Meanwhile, if someone likes changes from week to week, then he or she should take WUP. The biggest disadvantage of using these periodisation models could be the tiredness during this period, which sometimes could have a big influence on the specific accompanying workout for the actual sport. There could also be disturbing influences in the technical and coordinative training in the form of motoric deficits during this time.

Future research should focus on the effects of resistance training volume on protein synthesis, and other cellular and molecular changes that may impact changes in anthropometry, strength and psychophysical values.

Dedication

Our special thanks go to Fredrick C Hatfield, who surprisingly passed away on 14 May 2017 and who provided the impulse for this study with his famous training system. In memory of him we would like to dedicate these results to him.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

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