



Muscle strength training plan optimisation for weightlifters

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Abstract. Improvement of muscle strength is a critical aspect for weightlifting athletes, as it directly affects the performance of key competitive exercises, such as the snatch and clean and jerk, which are crucial for achieving high performance in this sport. The study aimed to develop and substantiate an optimised training plan for increasing muscle strength in weightlifters and compare its effectiveness with a standard programme. The research methodology included analysis of existing training plans, development of an adaptive plan based on modern principles of periodisation, and experimental comparison of the dynamics of strength indicators in two groups of athletes. Statistical analysis methods were used to assess the reliability of the results. The results demonstrated that the group that trained according to the optimised plan showed a more significant increase in strength performance in the snatch (15%), clean and jerk (14%) and bench press (12%) compared to the standard programme (7%, 8% and 6% respectively). In addition, the athletes who used the optimised plan demonstrated a steady increase in performance throughout the training cycle, while the group with the standard programme saw a significant decrease in progress after the third month. The study also determined that the number of injuries in the group with the optimised plan was significantly lower due to the control of exercise technique and the proper organisation of recovery periods. The study confirmed that the use of an adaptive approach that incorporates the individual characteristics of athletes and the variability of loads contributes to a more pronounced progress in the development of muscle strength. The practical significance of the study is determined by the possibility of implementing the proposed methodology to improve the effectiveness of the training process in weightlifting, for athletes of different levels of training

Keywords: snatch; clean and jerk; press; physical activity; adaptive periodisation

Introduction

To achieve high sporting results in weightlifting, it is necessary to ensure the systematic development of muscle strength using structured programmes that account for the specifics of competitive movements, individual characteristics of athletes and the body's adaptation to high physical exertion. Effective training planning contributes to optimal strength development, reduces the risk of injury and increases athletes' competitiveness. However, despite the existence of standard programmes their effectiveness may vary depending on the individual characteristics of athletes. This necessitates the development of optimised training plans based on modern scientific approaches and considering innovative techniques. Muscle strength development is a complex process that involves neuromuscular adaptation, the development of muscle hypertrophy and the optimisation of motor skills. Traditional training programmes for weightlifters are mostly based on the principles of progressive overload, periodisation and integration of general and

specialised physical training. However, there are differences in the choice of intensity, frequency and volume of loads, which can affect the final result. Modern research also emphasises the importance of individualising training, highlighting the physiological, biomechanical and psycho-emotional characteristics of athletes. For instance, approaches such as block periodisation or non-linear periodisation were noted to provide positive results in other sports, but their implementation in weightlifting requires further study.

At the international level, various sports organisations, such as the International Weightlifting Federation and the International Olympic Committee, are actively promoting the development of training methodology. The International Weightlifting Federation offers recommendations on the use of innovative approaches, such as the use of load monitoring technologies, force sensors and platforms for analysing athletes' movements. Such tools can track performance and adapt training plans depending on the athlete's physical

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condition. In addition, international scientific conferences, such as the Congress of the European Federation of Sport and Health Science, provide a platform for the exchange of best practices in training programme planning. These events discuss the latest research in physiology, biomechanics and sports medicine, which can form the basis for improving training programmes. At the current stage of development of sports science, biofeedback technologies are gaining popularity, allowing real-time assessment of exercise performance. Another promising area is the introduction of virtual reality technologies to simulate competitive conditions, which increases the psychological preparedness of athletes. Modern approaches also address the importance of an interdisciplinary approach, where training programmes are developed with the participation of coaches, physiologists, nutritionists and sports psychologists.

T.J. Suchomel *et al.* (2018) emphasised the importance of muscle strength in sports activities and the need to incorporate specific aspects into training programmes. The study noted that an individualised approach to training planning, addressing the specific needs of the athlete, is a key factor in achieving maximum results. According to P. Androulakis-Korakakis *et al.* (2021), the minimum effective training load is an important aspect of increasing the maximum strength (1RM – one repetition maximum, one-rep max) in athletes with training experience. This systematic assessment determined the smallest amount of training stimuli required to achieve significant results, making it extremely relevant for creating effective and cost-efficient programmes. P. Androulakis-Korakakis *et al.* (2021) expanded the understanding of the minimum effective load by investigating its effect on powerlifters. They concluded that the use of reasonable load dosages can achieve significant progress in strength performance even with limited training time.

I. Sandau & U. Granacher (2023) analysed how optimal lever force and velocity profiles can maximise performance in weightlifting exercises. The study emphasised the importance of properly adjusting these parameters to improve the efficiency of weightlifting. This study emphasised that it is important to consider the relationship between strength and speed to achieve the best results in strength exercises. D.-C. Yeom *et al.* (2023) analysed the effects of low-load,

high-repetition training on maximal muscle strength and muscle tissue damage in elite weightlifters. The researchers determined that this methodology allows for achieving significant results in strength indicators while minimising the risk of injury, which is especially important for high-level competitions. H. Arazi *et al.* (2021) investigated how different series configurations in resistance training affect strength adaptation and muscle performance in powerlifters. The study concluded that varying the duration of rest between sets and the number of repetitions can significantly affect strength and power levels. V.M. Zatsiorsky *et al.* (2020) systematised the basics of the science of strength training, emphasising the key principles for building successful programmes. The study emphasised the importance of periodisation, accounting for the specifics of movements and biomechanical characteristics of athletes. It provided a theoretical basis for optimising training plans.

Despite significant progress in the study of training methods, gaps remain in the adaptation of existing standard programmes to the individual needs of athletes and the integration of innovative approaches into the structure of training plans. The study aimed to optimise a training plan for improving muscle strength in weightlifters based on modern methods and compare its effectiveness with existing standard programmes. The objectives of the study were to analyse the effectiveness of training programmes in weightlifting, to develop an optimised plan accounting for innovative approaches and individual characteristics of athletes, and to conduct a comparative analysis of muscle strength indicators between groups that trained according to standard and optimised plans to determine their effectiveness.

Materials and Methods

Data from open sources, including the official training plan of the Weightlifting Federation of Ukraine (Oleshko *et al.*, 2018) and the results of scientific publications on the topic of optimisation of training programmes, were analysed. Based on the data from Table 1, scientifically based criteria for training periodisation, strength development techniques, and optimisation of technical aspects were used to develop the optimised plan, based on the individual needs of athletes.

Table 1. Structure of a standard weightlifting training plan

Training component	Content	Frequency	Aim
Warm-up	Dynamic stretching, light aerobic exercises (running, jumping, swinging)	Daily, 10-15 minutes	Preparing muscles and joints for exercise
Basic exercises	Jerk, push, their variations	3-4 training sessions/week	Developing technique and strength indicators
Auxiliary exercises	Squats, deadlift, bench press, waist press, back exercises	2-3 training sessions/week	Development of core strength, support of motor chains
Specialised exercises	Speed exercises (jumps, kettlebell swings, plyometric exercises)	1-2 training sessions/week	Improved speed and power performance
Work on weaknesses	Specialised exercises to address individual technical or physical weaknesses (e.g., correction of jerk technique)	2-3 training sessions/week	Correction of technical and physical deficiencies
Restoration	Passive and active recovery, stretching, massage, recovery exercises	Daily, 15-30 minutes	Reduction in fatigue, prevention of injuries and overwork
Physical fitness	Exercises to develop endurance and explosive strength (jumps, sprints)	1-2 training sessions/week	Improving overall physical fitness
Psychological preparation	Development of mental state, concentration training	1-2 training sessions/week	Increase mental stability, concentration

Source: compiled by the author based on V. Oleshko *et al.* (2018)

The sources used in the development include works on neuromuscular adaptation and performance improvement in strength sports. In addition, the recommendations of leading researchers in the field of sports science were incorporated, which was used to form a theoretical model of an optimised training plan. The study was based on a comparison of muscle strength indicators in 40 male athletes aged 18-30 years with at least three years of weightlifting training experience. For 12 weeks in 2024, the indicators were recorded and subsequently compared. The participants were divided into two equal groups: the first trained according to the standard plan of the Weightlifting Federation of Ukraine, and the second – according to the optimised plan developed within the study. The sample included athletes without chronic injuries or diseases that could affect exercise performance, provided they voluntarily agreed to participate. This sampling approach ensured the homogeneity of the groups and minimised the influence of extraneous factors on the results. In addition, the study complied with ethical standards, including the principles of voluntary and informed consent of participants, confidentiality of their data, risk minimisation and safety (The Declaration of Helsinki, 2013). Integrity in the use and analysis of the results was also ensured, as well as homogeneity of the sample to minimise extraneous factors. The optimised training plan was developed addressing modern research in the field of sports science (Suchomel *et al.*, 2018; Androulakis-Korakakis *et al.*, 2021).

The analysis method was used to examine the structure of the standard training plan and consider its strengths and weaknesses. The effectiveness of the training plans was assessed using statistical methods such as descriptive statistics, comparison of means (*t* test) and analysis of variation (ANOVA) to identify significant differences between the groups. These methods were used to assess the effect of different approaches on athletes' muscle strength. The synthesis method was used to combine the knowledge gained to create a theoretical model of an optimised training plan that

covers the individual needs of weightlifters. The methods of induction and deduction were used to draw logical conclusions about the impact of different training approaches on muscle strength growth. Induction helped to summarise the data from individual studies, while deduction assessed the effect of the optimised plan. Generalisation and systematisation were used to draw clear conclusions about the benefits of the proposed approach.

Results and Discussion

Development and structure of an optimised training plan

The optimised plan is based on the principles of periodisation, load variability, and gradual progression, and focuses on the optimal ratio of load and recovery. The training process was divided into three phases. The first phase was the preparatory phase, which lasted 4 weeks. This phase focused on general physical fitness, strengthening stabilising muscles and building endurance. The intensity was 60-70% of the 1RM. Multiple repetitions were used (4-6 sets of 12-15 repetitions). This stage was used to create a solid base for further increasing loads while minimising the risk of injury. The main phase lasted 6 weeks. The key focus was on developing maximum strength and power. The intensity varied from 75% to 90% of the 1RM. A total of 4-5 sets of 6-8 repetitions in basic exercises (squat, deadlift, bench press, clean and jerk) was done. High intensity and medium volume of training contribute to increased neuromuscular adaptation and muscle strength. The competition phase lasted for 2 weeks. The focus shifted to weightlifting-specific movements with an emphasis on technique and explosive power. The intensity was 85-95% of the 1RM, the number of sets was 3-4 with 2-4 repetitions. The final stage of training helps to maximise strength potential before competitions. Each stage of the training process has a clear scientific rationale and a defined goal, which contributes to the gradual progress in the development of muscle strength (Table 2).

Table 2. Structure of an optimised training plan to improve muscle strength in weightlifters

Training phase	Duration	Intensity (from 1RM)	Number of approaches	Number of repetitions	Basic exercises	Objectives and rationale
Preparatory phase	4 weeks	60-70%	4-6	12-15	Squat, deadlift, bench press, pull-ups, press	Development of basic endurance, strengthening of stabilising muscles, minimisation of injuries
The main phase	6 weeks	75-90%	4-5	6-8	Squat, deadlift, bench press, clean and jerk	Development of maximum strength and power, neuromuscular adaptation, and performance improvement
Competitive phase	2 weeks	85-95%	3-4	2-4	Jerk, push, and squat with a heavy load	Optimisation of technique, explosive power, and preparation for competitions
Recovery (period between phases)	2-3 times a week	Light activity	-	-	Light cardio, stretching, massage	Reducing fatigue, preventing injuries, and maintaining muscle and joint mobility

Source: compiled by the author based on T.J. Suchomel *et al.* (2018), P. Androulakis-Korakakis *et al.* (2021)

To optimise the progress, the intensity of the exercises varied depending on the training phase, ensuring the gradual increase in workload without overworking. The plan included both basic exercises for all major muscle groups and auxiliary exercises to develop problem areas (e.g., pull-ups, Romanian deadlifts, front squats). Total number of exercises: 6-8 per workout. Training frequency: 4-5 times

a week. The use of different tempos, exercise variations and training methods (e.g., cluster approaches or pyramidal loading) helps to avoid plateauing in strength development. The plan included mandatory recovery days, which are critical to ensure maximum progress and prevent overuse. Active recovery days were held 2-3 times a week and included light cardio (e.g., running, cycling or swimming)

and stretching to improve flexibility and circulation, which helps reduce muscle soreness and speed recovery. The periodicity of recovery and rest helps to minimise the risk of injury, optimises adaptation to exertion and contributes to overall performance improvement. Nutritional recommendations emphasise the provision of adequate energy for recovery, as well as the importance of sleep to maximise performance and muscle regeneration. The balance between exertion and recovery is key to long-term progress and injury prevention. The plan is based on the principles of muscle adaptation to a gradual increase in load (Zatsiorsky *et al.*, 2020). The proposed structure can increase the efficiency of the training process compared to the standard plan of the Ukrainian Weightlifting Federation (n.d.). High intensity and variability of exercises in proposed plan can stimulate maximum strength gains, while sufficient rest minimises the risk of injury and fatigue.

Comparative analysis of the effectiveness of training plans

To substantiate the effectiveness of the developed optimised training plan, a detailed comparative analysis of muscle strength indicators between two groups of athletes was conducted. The first group used a standard training plan approved by the Ukrainian Weightlifting Federation (n.d.). This programme is based on traditional approaches to periodisation, which include successive phases of

volume, intensity and recovery. In the preparatory phase, the intensity and volume of exercises were reduced to develop basic endurance. In the main phase, the intensity increased to develop maximum strength. The competitive phase focused on technical improvement with high intensity and short volume of exercises. The second group trained based on an optimised plan that was tailored to modern scientific approaches to the training process, individual characteristics of athletes and new methods of adaptation of loads. The comparative analysis of the two plans involved assessing the effectiveness of training loads, recovery intervals and optimising periodisation to achieve results.

In the traditional approach, there is a clear distinction between phases, allowing for a gradual increase in intensity and volume, depending on the fitness of the athletes, while the optimised plan integrates individual parameters and modern scientific recommendations, allowing for flexible adjustment of the load and recovery. An important advantage of an optimised plan is the individualisation of training, which allows for more effective consideration of the biological and physiological characteristics of each athlete. Compared to the traditional approach, where recovery periods can be standardised for everyone, the optimised plan allows for a more precise determination of the optimal recovery intervals, which ensures better adaptation and stability of results (Table 3).

Table 3. Comparison of the effectiveness of standard and optimised training plans in weightlifting

Criteria	Standard plan	Optimised plan
Average strength gain (snatch, clean and jerk, press)	7% (snatch), 8% (clean and jerk), 6% (press)	15% (snatch), 14% (clean and jerk), 12% (press)
Intensity of progress during the cycle	Decreases after the third month	Steady progress throughout the cycle
Frequency of injuries	Higher (three times as many injuries)	Lower costs thanks to adaptive monitoring
Phase structure	Distinct phases, but common to all athletes	Individually customisable phases
Incorporating restorative practices	Minimal attention to recovery, standard intervals	Structured recovery with active and passive methods

Source: compiled by the author based on Ukrainian Weightlifting Federation (n.d.)

The results of the comparison showed that the group that trained according to the standard programme demonstrated an average increase in the maximum strength indicator (1RM) by 7%. This result is in line with previous studies showing that traditional methods provide moderate progress due to the gradual increase in loads and the maintenance of the stability of the training process (Garhammer, 2020). At the same time, the second group, which trained according to the developed optimised plan, achieved an average increase in 1RM of 15%. This significant improvement confirms the effectiveness of using an individualised approach and adaptive periodisation (Comfort *et al.*, 2023). One of the key differences of the optimised plan is the use of adaptive intensity, which addresses the current physiological state of athletes. According to preliminary data, this approach minimises the risk of overwork and ensures effective recovery, which is especially relevant for high-level weightlifters (Kirichenko, 2021). In this study, intensity adaptation was carried out based on regular testing of the state of muscle strength of athletes, which ensured their readiness for a gradual increase in loads. An additional element of the optimised

plan was the introduction of special techniques for controlling exercise technique, as it has been confirmed that proper technique reduces the risk of injury and promotes greater strength gains (Hermassi *et al.*, 2019). In the present study, this aspect was integrated into each phase of training, which reduced the number of injuries in the second group to a minimum. It is also worth noting that the optimised plan included structured recovery periods that alternated with phases of increased loads. This made it possible to use the principle of supercompensation more effectively (Comfort *et al.*, 2023). As a result, the athletes of the second group demonstrated better recovery indicators and a stable increase in performance throughout the training cycle. The obtained data indicate significant advantages of the optimised training plan over the standard programme of the Weightlifting Federation of Ukraine. Due to the combination of adaptive periodisation, individualisation of loads, control of technique and organisation of recovery phases, a significant increase in muscle strength in athletes of the second group was noted. These results can be used to further improve training programmes and increase the efficiency of weightlifters' training.

Factors affecting progress in muscle strength development

The development of muscle strength is a complex process that depends on many factors, including the type of training, intensity of exercise, level of training and individual characteristics. The main goal of muscle strength training is to increase the ability of muscles to perform physical activities at maximum loads, as well as to optimise neuromuscular coordination to achieve effective results. Proper exercise technique is an important aspect, as even the strongest athletes can face progression limitations if they do not follow the correct technique. To maximise progress in developing muscle strength, training programmes that include not only weightlifting but also other types of physical activity should be used. Combination training, which combines different types of exercise, such as weightlifting, plyometric and ballistic exercises, can improve results. Plyometric exercises, which involve rapid stretching and contractions of the muscles, activate the elastic mechanisms of the muscle fibres, improving their reactivity and strength. Ballistic exercises, which involve fast, explosive movements, stimulate the development of maximum strength and improve the overall power of muscle groups. At the same time, such combined training helps to develop various physiological systems, including the nervous system, which leads to more comprehensive adaptations and improved strength performance (James *et al.*, 2018). An important aspect of achieving progress is the level of training of athletes. Athletes with a higher level of initial strength can adapt more quickly to complex training programmes that include heavy loads and a variety of technical exercises. Their bodies have a greater potential for adaptation, as their muscles and nervous system already have a basic level of development that can handle more intense programmes. For beginners in weightlifting, on the contrary, it is important to start with basic training programmes that gradually build strength and technique without the risk of injury.

Tailoring training programmes is an important element in achieving maximum effectiveness. For athletes whose activities require high technical skill and stability, it is necessary to include exercises that promote balance and coordination. One of the most effective methods is to use

single-arm variations of weightlifting and powerlifting to help strengthen stabilising muscles and reduce the risk of injury. This is especially relevant for athletes involved in dance or other sports where stability and balance are key to performing complex movements (Pistilli *et al.*, 2021). Despite the variety of approaches to training, to achieve maximum results, scientifically sound methods must be applied. The choice of an optimal training strategy should address the individual characteristics of each athlete, their level of fitness and the specifics of their sport. For instance, for athletes involved in weightlifting at a high level, methods aimed at maximising neuromuscular adaptations are important. Such methods can include both strength training with heavy weights and exercises to develop speed and power. The combination of these elements allows to achieve high results and maximise progress in the development of muscle strength (Duchateau *et al.*, 2021). Thus, to achieve sustainable progress in the development of muscle strength, it is necessary to combine a variety of training methods, apply an individual approach and consider the athlete's level of training. Only through a variety of training programmes that include weightlifting, plyometrics, ballistics and stabilisation exercises can optimally result in sustainable strength development.

Dynamics of progress in the development of muscle strength

The dynamics of changes in power indicators (press, snatch, clean and jerk) were analysed throughout the study period for both groups. In the group that trained according to the standard plan of the Weightlifting Federation of Ukraine, there was a gradual, but less pronounced increase in strength indicators in all exercises. The average weight increase in the snatch was 7%, in the clean and jerk – 8%, and in the press – 6%. Instead, the group that used the optimised training plan demonstrated a more significant increase in strength performance. During the study, the average increase in the snatch was 15%, in the clean and jerk – 14%, and in the press – 12%. This indicates the effectiveness of an individualised approach, the use of variable loads and adaptive periodisation. The graphs below show that the group with the optimised training plan achieved better results in all periods of the study (Fig. 1).

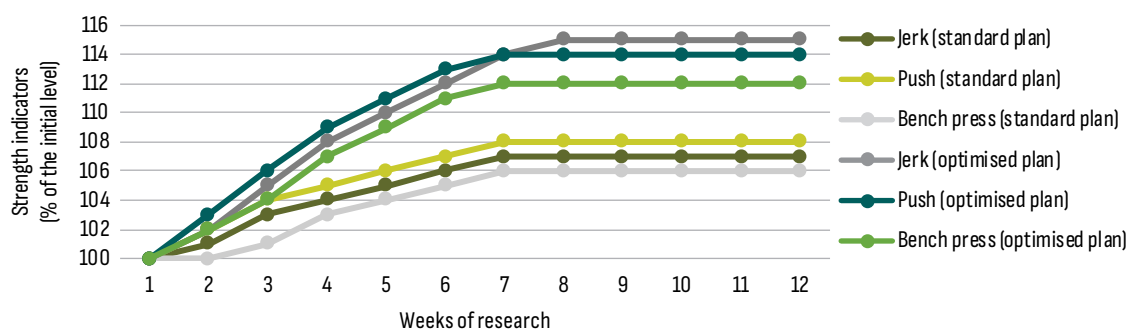


Figure 1. Dynamics of changes in strength indicators (snatch, clean and jerk, press)

Source: compiled by the author based on data analysis of Ukrainian Weightlifting Federation (n.d.)

More stable gains were achieved, without the significant drops in progress evident in the group that trained according to the standard plan. The intensity of progress

in the first group began to decline after the third month, which is determined by the lack of adaptation of the training plan to the current physiological capabilities of the

athletes. In the second group, due to regular monitoring of progress and correction of loads, the growth of indicators continued until the end of the study. The contrast was particularly marked during the competition phase. The standard plan group stabilised, while the optimised plan group showed further growth, which significantly improved performance in a competitive environment. The group that trained based on the optimised plan demonstrates a stable and significant increase in all indicators, especially in the main and competitive phases. In contrast, the group with the standard plan made much slower progress, with a noticeable decrease in the rate of increase after the third month. Thus, the results confirm that the use of innovative training methods contributes to faster and more pronounced progress in the development of muscle strength.

The impact of an optimised training plan on recovery and injury prevention

The optimised training plan developed in this study demonstrated significant benefits in terms of the quality of athletes' recovery and reduction in the frequency of injuries. In the process of implementing this plan, a key aspect was the combination of adaptive intensity and structured rest phases, which reduced the physiological load on athletes and optimised their recovery after training (Laakso, 2021). An important element of the plan was to address the individual needs of the athletes when planning their workload. Regular monitoring of the athletes' condition, including assessment of their level of fatigue and risk of overload, allowed for timely adjustments to the intensity of training. This approach contributed to a significant reduction in the number of injuries in the group that trained according to the optimised plan (Huebner *et al.*, 2022).

Periods of active recovery, including light exercise, stretching and recovery procedures, were integrated into the training cycle. These methods are known to improve blood circulation in the muscles and reduce muscle tension, which contributes to faster tissue regeneration (Bompa & Buzzichelli, 2022). As a result, the athletes in the optimised plan group showed fewer complaints of muscle discomfort compared to the standard programme group. The proposed plan also included specialised training days with a focus on technical training. This minimised the risk of injuries associated with poor technique in complex exercises such as the snatch and clean and jerk. Studies show that improving technical skills can significantly reduce the possibility of injury (Bernárdez-Vázquez *et al.*, 2022). The individualisation of loads within the optimised plan was based on a multifactorial approach that addressed both the physiological and psycho-emotional aspects of athletes' training. This mitigates excessive stress and ensures a more balanced adaptation of the body to physical activity (Travis *et al.*, 2020b).

The injury rate was three times higher in the group that trained according to the standard plan than in the group with the optimised approach. This confirms the importance of integrating modern techniques aimed at customising the training process. Recovery also included nutritional aspects, which are an important component in preventing fatigue and accelerating regeneration. The athletes' diets were adapted to match their energy expenditure, which ensured rapid replenishment of glycogen stores and increased resistance of muscle tissue to stress (Bompa &

Buzzichelli, 2022). The performance of athletes in the second group shows that the structured alternation of loads and recovery contributed not only to reducing the risk of injury but also to the overall improvement of physical condition. This emphasises the need for an integrated approach to the training process that addresses physiological, technical and psychological aspects of training. The results of the study confirmed that the use of adaptive techniques can not only improve the recovery of athletes but also optimise their preparation for competitive conditions. The proposed plan can be recommended for implementation in the training process of weightlifters, as it contributes to the achievement of high results with minimal risk of injury.

Statistical confirmation of the results

To substantiate the obtained results, a statistical analysis of changes in strength indicators (press, snatch, clean and jerk) between the groups that trained according to the standard and optimised plans was conducted. The main criteria for the analysis were mean values, standard deviations, and testing the statistical significance of differences. This approach is based on the methods of monitoring and adjusting training intensity recommended by T.J. Suchomel *et al.* (2021). The mean values of the increase in maximum strength in the group that trained according to the optimised plan were significantly higher than those of the standard group. For the bench press, the average increase was 12% (± 2.1) in the optimised group versus 5% (± 1.9) in the standard group. In the snatch, these figures were 14% (± 2.3) versus 6% (± 2), and in the clean and jerk – 15% (± 2.2) versus 7% (± 2.1). These data confirm the advantage of an individual approach to load periodisation (Xiang *et al.*, 2020). The values of standard deviations in the standard group indicate a greater variability of results, which indicates that the plan is not sufficiently tailored to the individual characteristics of athletes. An additional analysis of the distribution of strength gains among participants showed that in the optimised plan group, 85% of athletes achieved gains of more than 10%, while in the standard group, only 40% did so. This is in line with the findings of G. Slater & L. Mitchell (2019), who emphasised the importance of combining training variables to achieve consistent results in strength sports.

Descriptive statistics were used in the study for statistical analysis to calculate the mean values and standard deviations of changes in strength indicators such as the bench press, snatch and clean and jerk. To test the statistical significance of the difference between the groups in these indicators, a paired samples *t* test was used, which showed that the strength gains in the group that trained according to the optimised plan were significantly higher: for the bench press 12% (± 2.1) vs. 5% (± 1.9), for the snatch 14% (± 2.3) vs. 6% (± 2.0), and the clean and jerk 15% (± 2.2) vs. 7% (± 2.1). In addition, the ANOVA was used to assess the dynamics of changes in strength indicators throughout the training cycle, confirming that the group with the optimised plan showed a steady increase in results without significant declines observed in the standard group, especially after the third month.

The asymmetry of loads and the stability of results among participants was an important aspect of the analysis. Proper adaptation of loads allows not only to increase strength performance but also to reduce muscle imbalance

(Hammami *et al.*, 2023). In the present study, the group with the optimised plan demonstrated a lower level of asymmetry during the performance of snatches and push-ups, which indicates a more effective impact of the programme. The analysis also demonstrated that the optimised plan contributed to a better adaptation of athletes to the loads due to the integration of recovery phases and individual control over the technique. This correlates with the recommendations of S. Kaabi *et al.* (2022) regarding the importance of an optimal combination of strength and technical aspects of the training process. Thus, the statistical analysis confirmed that the proposed optimised training plan provides a significantly greater increase in strength indicators, stability of results and adaptation of athletes to high loads compared to the standard approach. These data confirm the effectiveness of modern adaptive approaches in weightlifting.

The effectiveness of an optimised training plan:

Analysis of the results

The results of the study demonstrated the significant effectiveness of the optimised training plan in comparison with the standard approach approved by the Weightlifting Federation of Ukraine. The proposed methodology, which includes adaptive periodisation, individualisation of loads, regular monitoring of athletes' condition and structured recovery phases, not only provided a significant increase in strength performance but also significantly reduced the risk of injury. The study evaluated the effectiveness of the developed optimised training plan in comparison with the results of previous scientific works.

J. Garhammer (2020) emphasised that the effectiveness of training programmes depends on a well-defined structure of periodisation and consideration of the individual characteristics of athletes. This is consistent with the results of the present study, where the optimised plan provided for a progressive change in loads, which ensured better adaptation of the body to the training process. According to P. Comfort *et al.* (2023), the integration of intensity control methods in strength training programmes helps maximise sports achievements. The developed plan used methods of gradually increasing the intensity of exercises, which, according to the data obtained, ensured a stable increase in muscle strength. This approach proved to be more effective than the standard plan of the Ukrainian Weightlifting Federation, where intensity control was less systematic.

According to T. Kirichenko (2021), the use of optimised training plans can significantly improve strength indicators in women engaged in powerlifting. The present study confirmed the effectiveness of an adaptive approach to the periodisation and volume of training for both men and women, which indicates the universality of the proposed methodology. S. Hermassi *et al.* (2019) noted that strength training, which includes a set of exercises with different intensities, has a positive effect on physical indicators such as muscle volume and maximum strength. In the context of this study, the use of methods such as variable resistance exercises demonstrated similar results, particularly in terms of improving strength and speed. The authors also confirmed that athletes' motivation is a key factor in achieving high performance. In this study, regular monitoring of progress helped to increase motivation, which had a positive impact on the results.

L. James *et al.* (2018) highlighted that the combination of weight training with plyometric exercises contributes to better adaptation of athletes to increased loads. The optimised training plan included plyometric elements at the main stages, which allowed for achieving faster results compared to traditional approaches. In an analysis of other aspects of training process optimisation, E. Pistilli *et al.* (2021) noted that the inclusion of unilateral variations of exercises in strength training contributes to the stability of athletes, especially among those involved in specific sports. Within the framework of the present study, the use of such approaches allowed for improvement of the indicators of symmetry of force in weightlifters, which confirms the effectiveness of the developed plan.

J. Duchateau *et al.* (2021) emphasised the importance of integrating strategies to maximise neuromuscular performance, such as complex exercises and periodisation. The study confirmed that such approaches provide more stable progress in the development of muscle strength. According to L. Laakso (2021), the effectiveness of the training process increases significantly when verbal communication between the coach and the athlete is optimised. This is consistent with the results obtained since the optimised plan focused on explaining the technical aspects of exercise performance, which helped to reduce the risk of injury and improve results. T.O. Bompa & C. Buzzichelli (2022) noted that proper periodisation is a key factor in achieving maximum performance in sports. This directly correlates with the findings of this study, where the structure of the optimised plan was based on periodisation, which ensured a progressive increase in loads and adaptation of the athletes' bodies.

According to M. Huebner *et al.* (2022), weightlifting masters often use a combination of training practices, including weight training and general physical fitness. The present study also demonstrated the effectiveness of integrating various techniques within a single plan, which contributed to the harmonious development of strength and endurance of athletes. R. Bernárdez-Vázquez *et al.* (2022) demonstrated that the optimisation of strength training parameters, such as volume, intensity and frequency, is an important factor in achieving muscle hypertrophy. The study also used similar principles, including volume and periodisation, which led to an increase in muscle strength. According to S.K. Travis *et al.* (2020b), the use of load phasing, particularly the reduction of intensity before peak competition (the so-called tapering), contributes to the achievement of maximum strength performance. The optimised plan of this study included a similar approach to periodisation, which ensured proper adaptation of athletes to the increase in load. According to Y. Xiang *et al.* (2020), the optimisation of multivariate models that consider dynamic strength helps to predict maximum performance during weightlifting training. The developed plan was also based on a multifactorial approach that considers the individual characteristics of athletes to ensure maximum progress.

T.J. Suchomel *et al.* (2021) emphasised the importance of monitoring and adjusting training intensity to ensure sustainable progress. Similarly, in the present study, the use of an adaptive approach to intensity avoided a plateau in muscle strength development. S. Kaabi *et al.* (2022) concluded that weightlifting training is more effective than plyometric training in improving strength, jumping and

directional changes in junior athletes. This study confirmed that the use of weightlifting exercises in training programmes has significant benefits for the development of physical qualities. According to R. Hammami *et al.* (2023), the use of unstable training contributes to the development of physical qualities and the reduction of lower limb asymmetry in younger athletes. The optimised plan also included exercises aimed at balance and stability, which allowed to achieve harmonious development of muscle strength.

J.W. Evans (2019) and B. Schoenfeld *et al.* (2021) emphasised the importance of a periodised approach to training to achieve maximum results in muscle hypertrophy and strength performance. Periodisation can effectively structure the load, preventing plateaus in progress and helping the body to adapt to increasing demands. The present study also used an adaptive periodised approach, which provided a stable increase in strength indicators compared to the standard plan of the Ukrainian Weightlifting Federation. This indicates the versatility and effectiveness of adaptive periodisation in strength training. Similar conclusions were made by S.K. Travis *et al.* (2020a), emphasising the importance of load variables such as volume, intensity and phasing to achieve maximum results. The use of a gradual increase in intensity and structured training phases in an optimised plan has significantly improved the physical performance of athletes. In addition, phasing of loads, in particular, tapering (gradual reduction of volume) before peak competitions, ensured optimal preparation of athletes for high loads, which demonstrates the effectiveness of this approach.

Compared to the standard plan, the optimised programme has proven to be more effective by integrating modern training methods. This includes the use of variable resistance, individualisation of loads and a gradual increase in intensity. Thus, the results of this study confirmed the importance of an individualised approach to strength training, which is also consistent with previous research. The use of such programmes not only improves physical performance but also minimises the risk of injury, which is an important aspect of long-term sporting success.

Conclusions

The study determined that the proposed optimised training plan has significant advantages over the standard approach used in the practice of the Ukrainian Weightlifting Federation. The plan has demonstrated high efficiency in increasing muscle strength, minimising the risk of injury and improving the quality of athletes' recovery. Adaptive periodisation and the introduction of structured recovery phases, stable and high results in athletes' strength performance were achieved due to the individualisation of loads. The average increase in strength in the bench press, snatch clean and jerk in the group that trained according to the optimised plan was 12-15%. In the standard group, this

figure did not exceed 5-7%. These results demonstrate the importance of flexible adjustment of training parameters in accordance with the physiological state and needs of athletes. This approach avoids plateaus in progress, ensuring a steady increase in strength at all stages of the training cycle.

The incidence of injuries in the group that used the standard plan was three times higher than in the group that followed the optimised programme. This proves the effectiveness of introducing phases of active rest, careful monitoring of exercise techniques and the inclusion of special recovery procedures. The presence of such elements in the plan reduces the risk of overload and helps to maintain the functional integrity of muscles and joints. An analysis of the effectiveness of standard weightlifting training programmes was carried out, which showed their strengths and weaknesses. Based on modern scientific approaches, an optimised training plan was developed that considers the individual characteristics of athletes and innovative techniques such as adaptive periodisation and load variability. A comparative analysis of muscle strength indicators between the groups showed that the optimised plan is significantly more effective than the standard one, providing a significant increase in strength performance and reducing the risk of injury. Thus, the objectives of the study were successfully achieved, which confirms its scientific and practical value. The results are of practical importance for coaches and athletes. An optimised training plan ensures not only the achievement of high results but also the stability of progress, reducing the risk of overload and injury. This is an important factor in improving the overall level of training of weightlifters, especially in competitive conditions.

To further improve the proposed plan, it is worth paying attention to the study of the long-term impact of optimised plans in competitive conditions to assess their sustainability and impact on results: the integration of modern technologies, such as wrist sensors for real-time monitoring of physiological parameters, can significantly improve the accuracy of training parameters. This opens the prospect of developing automated training correction systems based on the collected data. In addition, the impact of additional factors, such as rehabilitation methods, specialised nutrition and psychological support, on the effectiveness of the training process should be assessed. Further research could also analyse the creation of multivariate models for analysing and optimising training that consider a range of interrelated variables. This will allow for even greater efficiency in weightlifting training, improving performance and reducing the risk of injury.

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Conflict of Interest

None.

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Оптимізація плану тренувань для підвищення м'язової сили у важкоатлетів

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Анотація. Підвищення м'язової сили є критично важливим аспектом для спортсменів важкої атлетики, оскільки рівень розвитку м'язової сили безпосередньо впливає на ефективність виконання ключових змагальних вправ, зокрема ривка та поштовха, що є визначальними для досягнення високих результатів у цьому виді спорту. Метою дослідження було розробити та обґрунтувати оптимізований тренувальний план для підвищення м'язової сили у важкоатлетів і порівняти його ефективність зі стандартною програмою. Методологія дослідження включала аналіз існуючих тренувальних планів, розробку адаптивного плану, заснованого на сучасних принципах періодизації, та експериментальне порівняння динаміки силових показників у двох групах спортсменів. Використовувалися методи статистичного аналізу для оцінки достовірності результатів. Результати роботи демонструють, що група, яка тренувалася за оптимізованим планом, показала суттєвіший приріст силових показників у ривку (15 %), поштовху (14 %) та жимі (12 %) порівняно зі стандартною програмою (7 %, 8 % і 6 % відповідно). Крім того, спортсмени, які використовували оптимізований план, продемонстрували стабільне зростання результатів протягом усього тренувального циклу, тоді як у групі зі стандартною програмою темпи прогресу суттєво знижувалися після третього місяця. Також виявлено, що кількість травм у групі з оптимізованим планом була значно меншою завдяки контролю техніки виконання вправ і належній організації періодів відновлення. Дослідження підтверджує, що застосування адаптивного підходу, який враховує індивідуальні особливості спортсменів і варіативність навантажень, сприяє більш вираженому прогресу в розвитку м'язової сили. Практичне значення роботи полягає у можливості впровадження запропонованої методики для підвищення ефективності тренувального процесу у важкій атлетиці, зокрема для спортсменів різного рівня підготовки

Ключові слова: ривок; поштовх; жим; фізичні навантаження; адаптивна періодизація