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Power and strength training plan for off and on season for teenage runners.

Bachelor's degree in Sports and leisure management

Thesis

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Abstract

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The primary goal of this thesis is to develop a design of power and strength training program tailored for sprinters during on and off season, aiming to optimize their overall athletic performance, speed, and explosive strength. Our investigation includes a thorough examination of the physiological and biomechanical elements of sprinting, coupled with a critical review of current training approaches. We seek to bridge existing gaps in the literature by crafting a power training regimen designed specifically for sprinters, offering evidence-based guidance to coaches and athletes for performance enhancement.

Partnering with Kajaanin Kipinä, an athletics club established in 1911. Dedicated to optimizing the performance of athletes, particularly in sprinting, our research focuses on providing a structured guide accessible to all. This involves imparting valuable insights into the principles of power training, emphasizing strength and speed enhancement. The fundamental objective is to formulate a comprehensive strength power training program specifically for sprinters during both on and off season.

The product was developed utilizing a systematic approach. This methodology offers a structured framework of steps to be followed from the inception to the completion of the thesis. The process commences with formulating research questions, conducting a literature review, extracting data, assessing quality, combining and analyzing data, and interpreting results. The ultimate outcome is the creation of an annual training regimen tailored for runners. This regimen provides the client with a comprehensive overview of strength and power training strategies for both the off and on seasons. It includes examples of resistance exercises for hypertrophy, strength, and power training. Additionally, crucial elements such as safety protocols and recovery strategies have been incorporated into the program.

The theoretical section elucidates the influence of strength training on speed enhancement. It furnishes readers with essential physiological and biomedical insights into the functioning of the human body.

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1 Introduction

Numerous factors significantly contribute to the enhancement of short-distance sprint performance, including running technique, comprehension of running mechanics, reaction time, strength, and power strength training. Within the context of this thesis, emphasis is placed on the critical examination of strength and power training. As physical training majors at Kajaani University of Applied Sciences, our thesis delves into the effects of resistance training on athlete performance, with a focus on creating a comprehensive power and strength training regimen. Partnering with Kajaanin Kipinä, an athletics club established in 1911 with approximately 240 members as of 2020, our research aims to provide reliable reccommendations for effective power and strength training methods.

Our motivation came from wanting to make a real-world impact on the training of youth athletes. Our belief is that proper strength training is one of the most important things we can do to keep young athletes healthy, performing at their best, and enjoying their sport for years to come. If this thesis can help coaches implement effective, age-appropriate strength training with their runners, it’s considered as a success.

In summary, this thesis aims to contribute to the field of athletic performance by developing a specialized power training program for sprinters. By providing coaches and athletes with evidence-based guidance, we aspire to enhance sprinters' explosiveness, speed, and overall athletic performance.

2 Commissioning party

Kajaani Kipinä Ry is a Kajaani athletics club founded in 1911. Kajaani Kipinä was initially a general club whose activities included, e.g., gymnastics, boxing, skating, baseball, and athletics. Over time, however, other sports have qualified, and today Kajaani Kipinä is a special athletics club. Its areas of operation include children's and youth athletics, adult sports, and fitness sports. Kajaani Kipinä has approximately 240 members (as of 2020). Kipinä is a Star Club that meets the quality requirements set by the Finnish Olympic Committee for children and youth activities. The club's operations are regularly audited to ensure high-quality operations. Kipinä has valuable traditions. Among the club's athletes, there have been many celebrities, e.g., high jumper, later president of the republic, Urho Kekkonen, gymnast Heikki Savolainen, and Olympic medalist shot putter Ville Pörhölä.

Kajaani Kipinä's junior activities include a coaching group for 11–14-year-olds, athletic schools and camps, a sports club, and children's athletic competitions. In the winter season, the athletics schools and the sports club run at Kajaanihalli, and in the summer season at Vimpel's athletics field. Camps are organized as much as possible, and children's athletic competitions are updated in the competition calendar and children's competitions in the winter season section. A child can join the athletic school at the age of 7. At the athletics school, a child can practice athletics up to the age of 15. You can transfer from the athletics school to a coaching group that is more goal-oriented than the athletics school at the age of 11. At the age of 15, there is an opportunity to transfer either from the athletics school or from the early youth coaching group to Kipinä's youth coaching group. The goal of our junior activities is to offer high-quality and versatile sports activities for children and young people in a safe environment. Training changes from playful training to more sport-oriented training as age increases. Growing up through exercise, being family-oriented, and being versatile are the most important principles of our junior activities. We currently have about 60 children in athletic schools and sports clubs. Skilled and trained instructors act as instructors.

2.1 Research purpose and aims.

Sprinting represents a multifaceted athletic discipline that integrates various components, including intricate techniques, strength, and power. In accordance with our agreement with the com-missioning party, our task involves formulating a comprehensive strength and power training plan tailored for adolescent athletes during both the on and off-season periods. To fulfil this objective, our primary focus is to engage in a thorough literature review, seeking scholarly works that address the fundamental inquiries posited in our thesis.

2.2 Research questions (Primary and secondary)

Primary:

a) What is the impact of strength and power training plans on the performance of teenage runners during both off and on seasons?

b) What is the difference in the program design used in off and on season?

Secondary:

a) What are the types of recovery that should be used during the program?

3 History of sprinting

Sprinting represents the epitome of explosive human performance, demanding a delicate balance between physiological strength and biomechanical efficiency. Athletes engaged in sprinting must cultivate explosive strength, speed, and power to compete at the highest levels, where the capacity to exert maximum force in the shortest time frame defines track performance. With the ultimate goal of elevating sprinters' performance to new heights, this thesis delves into the meticulous planning and execution of a power training regimen tailored to meet their specific requirements.

Running is at once the simplest and most varied of sports- and is surely the oldest form of efficient human locomotion. Marion Jones sprinting 100 meters with the grace of a greyhound or grey-haired Paul Reese running across the Unites States with the gracelessness of a mule are of the same heritage. Running is hardwired in all of us. An infant taking its first steps does not "learn how to walk." The infants first steps are at a tun as it launches itself full tilt into the world (Benyo & Henderson, 2002.)

The IAAF defines sprint disciplines as events up to 400 m with the Olympic distances being the 100, 200, and 400 m. The duration of sprint events is under a minute in length, with the marquee sprint event, the 100 m, lasting approximately 10 s. Sprint events have received considerable attention in the literature as posing an extreme of human performance. It should be noted that, though generally similar, within the range of 60–400 m there can be considerable differences in biomechanical and physiological factors that underlie successful performance. For example, you may see elite runners perform well in the 100 and 200 m, or 200 and 400 m, but in the modern era we have not seen an elite runner with high-level performance in both the 100 and 400 m. (Thompson,2017.)

3.1 Physiological Demands of Sprinting:

Because sprinting involves short but powerful bursts of effort, a thorough understanding of the physiological reactions essential to optimal performance is required. Anaerobic energy systems and fast-twitch muscle fibres play a major role in sprinting, as demonstrated by earlier studies that examined the metabolic pathways involved. Further research has examined the physiological demands of sprinting and shown how energy generation and oxygen supply must be carefully balanced during brief bursts of peak exertion.

The physiological characteristics of successful runners are different from those of sprinters and long-distance runners. Maximal oxygen uptake (V̇O2max), running economy and the anaerobic threshold are variables that have been shown to limit performance during long distance running, and rapid velocity and anaerobic variables have been shown to limit performance during sprinting (Brandon, 1995.)

While sprinting speed is clearly dependent upon the mechanical ability to apply high forces in short contact times, several physiological factors underlie this ability to generate force during sprint running. Sprint events rely heavily on anaerobic metabolism to support the high force output. The shortest of sprint events (duration <15 s) rely predominantly on the ATP-PCr system to supply the ATP needed for muscle contraction, whereas anaerobic glycolysis provides a greater percentage of the required ATP as distance increases (Cheetham et al. 1986; di Prampero et al. 2015). Thus, individuals with higher levels of anaerobic functioning will likely have better sprint running performance. The ability to generate force during sprint running is likely dependent on leg strength, power, and stiffness, as these factors have been shown to be correlated with sprinting performance (Chelly and Denis 2001; Bret et al. 2002). The importance of leg strength is further illustrated by the finding that age-related muscular atrophy and losses in muscle strength are associated with longer contact times, lower GRFs, and corresponding decreases in running speed (Korhonen et al. 2009). Skeletal muscle characteristics underlie the force demands with critical determinants of sprint performance consisting of muscle mass, fiber type composition, and fascicle length (Costill et al. 1976; Mero et al. 1981; Kumagai et al. 2000). The high mechanical output required for elite sprint running performance is achieved by a large number and cross-sectional area of type II fibers in the leg extensor muscles (Mero et al. 1981, 1983), which has recently been associated with the ACTN3 R577R and ACE I/D gene variants (Papadimitriou et al. 2016). Additionally, elastic energy storage and return is important for sprinting performance (Cavagna et al. 1971; Alexander 1991; Thompson 2017.)

Fluctuations in physiological factors such as core temperature (CTemp), heart rate (HR), ventilation (VE) and lactate concentration (La), may be associated with changes in running economy during competition. Thomas et al. investigated the effect of a simulated 5km race on RE, VE, CTemp, La and HR. Running economy was determined using a constant treadmill speed eliciting 80 to 85% of the athletes VO2 Max. Running economy decreased significantly and VE, C temp, LA and HR increased significantly from the beginning to the end of the five-kilometer run (Saunders er al, 2004.)

3.2 Biomechanical Factors to consider in sprinters.

In the biomechanics of sprint running, several crucial factors significantly influence performance. These include reaction time, technique, electromyographic activities, force production, neural factors, muscle structure, and additional elements such as stride length and frequency (Mero, Komi & Gregor, 1992.)

As mentioned, there are several biomechanical factors relevant to sprint running and how they can be influenced by power and strength training with weights. These factors include:

Force production:

Weight training contributes to increased muscular strength, allowing athletes to generate greater force during each stride in sprinting.

Muscular strength holds considerable importance in athletic performance, as it exhibits a robust correlation with enhanced force-time characteristics. This implies that athletes possessing greater muscular strength can expeditiously generate force, leading to improved proficiency in activities such as jumping, sprinting, and tasks involving changes of direction. Furthermore, athletes with increased strength levels typically demonstrate superior performance in skills specific to their respective sports (Shucomel, Stone & Nimphius, 2016.)

Joint Angles and Range of Motion:

A systematic review and meta-analysis of studies examining how resistance training impacts ROM was conducted by the team of authors involved in this study consists of individuals with expertise in areas such as exercise physiology, sports science, biomechanics, and physical therapy are Shahab Alizadeh, Abdolhamid Daneshjoo, Ali Zahiri, Saman Hadjizadeh Anvar, Reza Goudini, Jared Hicks, Andreas Konrad, and David Behm.

Resistance training improves range of motion (ROM) by increasing flexibility. According to a systematic review and meta-analysis, chronic resistance training with external loads can enhance ROM to a moderate magnitude. This improvement in ROM is observed regardless of whether resistance training is compared to stretch training or a combination of resistance training and stretch training. The study found no significant differences in ROM improvements between these training methods (Alizadeh et al., 2023.)

Resistance training induces changes in the musculotendinous units, including alterations in stiffness and compliance, which contribute to increased ROM. The discomfort associated with external torques during resistance training enhances stretch tolerance and allows individuals to push beyond their previous limits of discomfort. Additionally, resistance training leads to positive adaptations in joint ROM through controlled movement at the active joint range (Alizadeh et al., 2023.)

The analysis included 55 studies that compared the training effects of resistance training exercises with a control group, stretching group, or combined stretch and resistance training group on ROM in healthy participants. The results showed that resistance training increased ROM in all joints analysed, with no significant differences in the extent of ROM improvement between different joints. The study also found that resistance training was equally effective as stretch training in improving ROM, and there were no significant differences between resistance training and stretch training compared to stretch training alone (Alizadeh et al., 2023.)

Neural factors:

Neural factors influence sprint running training adaptations and acute responses, with neural adaptations playing a significant role in enhancing sprint performance. Factors such as changes in muscle activation patterns, improved motor unit recruitment strategies, increased nerve conduction velocity (NCV), and enhanced reflex responses contribute to superior sprint performance. For instance, alterations in the sequencing of muscle activation and fast twitch fiber recruitment can lead to more efficient movement patterns and improved sprint performance. Additionally, the speed of impulse transmission along the motor axon, as indicated by NCV, may impact sprint performance, with evidence suggesting that NCV may increase in response to sprint training (Ross, Leveritt & Riek, 2001.)

Stride length and frequency:

Stride length and frequency play a crucial role in running performance, particularly from a biomechanical perspective. In sprinting, elite athletes manipulate their stride length and frequency to optimize their velocity. The relationship between velocity, step length (SL), and step frequency (SF) is a topic of interest in biomechanical literature, with the understanding that elite sprinters' velocity can depend on either step length or step frequency as individual factors. During a maximal sprint, athletes can adjust their step length and step frequency to maintain their velocity. Studies have shown that the influence of SL and SF on sprint performance can vary from one individual to another, highlighting the importance of analyzing specific biomechanical variables within each athlete (Bezodis, 2012.)

Additionally, training programs can impact step length and step frequency, with increases in sprint velocity often occurring after phases of high-intensity sprint training following high volume weight training, indicating the relationship between force development and ground contact time. Joint kinetics, such as hip extension moments and ankle joint work, have been identified as key factors linked to sprint performance on a within-athlete basis, suggesting the importance of understanding these biomechanical variables in enhancing running performance (Bezodis, 2012.)

According to one study from University of Houston, the mechanics of stride length in sprinting are crucial for maximizing performance. Proper technique is essential to achieve an optimal stride length. To ensure an efficient stride length, the foot should strike the ground with the lower leg at a 90-degree angle to the ground, avoiding overstriding which can lead to braking and a decrease in stride frequency. Flexibility and strength also play a significant role in enhancing stride length. Flexibility allows for a full range of motion during running, contributing to an optimal stride length. As strength increases, the force applied to the ground with each stride should also increase, resulting in the ability to travel farther with each stride. Additionally, factors such as running mechanics, running workouts, and proper training cycles can all impact the mechanical aspects of stride length in sprinting (Baughman, Takaha, & Tellez, 1984.)

4 Resistance training

Resistance training is a modality of exercise that has grown in popularity over the past two decades, particularly for its role in improving athletic performance by increasing muscular strength, power and speed, hypertrophy, local muscular endurance, motor performance, balance, and coordination. Traditionally, resistance training was performed by a few individuals (e.g., strength athletes and those who strived to gain muscle hypertrophy, such as body builders). However, we now have a better understanding of the health-related benefits of resistance training; resistance training is now a popular form of exercise that is recommended by national health organizations such as the American College of Sports Medicine and the American Heart Association for most populations, including adolescents, healthy adults, the elderly, and clinical populations (e.g., those individuals with cardiovascular disease or neuromuscular disease). The resistance training program is a composite of acute variables that include: muscle actions used, resistance used, volume (total number of sets and repetitions), exercises selected and workout structure (e.g., the number of muscle groups trained), the sequence of exercise performance, rest intervals between sets, repetition velocity, and training frequency. Altering one or several of These variables will affect the training stimuli and potentially favor conditions, in which numerous ways exist to vary resistance training programs and maintain or increase participant motivation. Therefore, proper resistance exercises prescription involves the manipulation of each variable-specific to the targeted goals (Kraemer & Ratamess, 2004.)

According to a study from the Paediatric Clinics of North America, it has been established that young adolescents can engage in resistant training with weights. However, the key emphasis lies in ensuring that such training is undertaken in a safe and supervised manner. Strength training during childhood and adolescence offers various benefits, including enhancements in strength, bone density, balance, lipid profiles, fat-free mass, and personal self-esteem (Dahab & McCambridge, 2009.)

Research findings indicate that children can experience a substantial improvement in their strength, ranging from 30% to 50%, within a relatively short period of 8 to 12 weeks, provided they follow a well-designed strength training program. Nevertheless, it is crucial to recognize the potential risks associated with strength training, especially if not executed correctly. Injuries linked to this form of training, such as epiphyseal plate fractures and lower back injuries, are predominantly linked to factors such as equipment misuse, inappropriate weight selection, improper technique, or the absence of qualified adult supervision. Therefore, a meticulous approach to supervision and adherence to proper guidelines is imperative to ensure the safety and well-being of young adolescents engaging in resistant training (Dahab & McCambridge, 2009.)

Another study from Br J Sports Med had indicated that young adolescents can train with weights as long as they follow age-appropriate resistance training guidelines, have qualified supervision, and receive proper instruction on lifting techniques. Current research indicates that resistance training can be safe, effective, and beneficial for children and adolescents. When supervised and instructed properly, resistance training poses no greater risk of injury than other sports and recreational activities that young athletes regularly participate in. However, it is essential for teachers and coaches to be aware of proper resistance training procedures to prevent injuries that may result from unsafe behaviour, equipment malfunction, or lack of supervision. While some injuries related to youth resistance training have been reported, most can be attributed to inadequate professional supervision, poor exercise techniques, and inappropriate training loads. Therefore, with the right guidance and training programs designed by qualified professionals, youth resistance training can be a valuable tool for enhancing strength and reducing the risk of sports-related injuries among young athletes (Feigenbaum & Myer, 2010.)

Teenagers can start going to the gym for weightlifting according to academic articles when they are prepubertal or post pubertal adolescents. It is recommended that children and adolescents begin with low-resistance exercises until they perfect proper technique, and then gradually increase weight in 10% increments as they can perform 8 to 15 repetitions with good form. Workouts should include all muscle groups, be at least 20 to 30 minutes long, 2 to 3 times per week, and continue to add weight or repetitions as strength improves. Proper supervision, technique, and safety precautions are crucial to reduce the risk of injury, with an instructor-to-student ratio of no more than 1:10. Warm-up and cool-down periods with stretching techniques are also essential for safety and effectiveness (Myers, A. M., Beam, N. W., & Fakhoury, J. D. 2017.)

The difference between a young teenager and an old teenager in weightlifting lies in their response to strength training. Prepubertal children and postpubertal adolescents respond differently to strength training. Adolescents are capable of greater absolute gains due to higher levels of circulating androgens. Early physical training can lead to increased muscle cross-sectional area and strength, particularly in the erector multifidus and psoas musculature. Muscle cross-sectional area directly correlates with strength in trunk flexion and extension. Studies have shown that from 12 to 22 years of age, weightlifting training can produce positive alterations in body composition, cardiorespiratory variables, and motor fitness qualities, leading to improvements in strength, muscle mass, and overall physical performance (Myers, A. M., Beam, N. W., & Fakhoury, J. D. 2017.)

In summary, teenagers can safely engage in weightlifting under proper supervision and with age-appropriate training programs. Starting with low-resistance exercises, focusing on proper technique, and gradually increasing intensity can help teenagers improve their strength and overall health. The response to strength training varies between prepubertal and postpubertal adolescents, with older teenagers showing greater gains in strength due to hormonal changes and increased muscle mass. By following guidelines for safe and effective strength training, teenagers can benefit from improved physical fitness and well-being (McQuilliam, S. J., Clark, D. R., Erskine, R. M., & Brownlee, T. E. 2020.)

4.1 Resistance training for sprinters

Sprinters can enhance their sprint performance by integrating resistance training into their overall training routine, as research indicates its crucial role, especially in short and maximum-speed sprints across various sports. To optimize effectiveness, it is essential to focus on the specificity of training, tailoring exercises to target specific muscle groups based on the demands of sprinting. Plyometrics prove particularly beneficial for cultivating reactive strength, a vital component for maximum-speed sprinting. Tests measuring power consistently reveal strong correlations with longer sprints or sprints at maximum speed, underscoring the significance of explosive force qualities (Young, Benton, Duthie, & Pryor, 2001.)

For an effective training regimen, sprinters should consistently include resistance training exercises, integrating them into their routine. A periodized program can strategically incorporate specific exercises tailored for short sprints and maximum-speed sprints, progressively developing essential qualities for sprint performance. Coaches are encouraged to continually expand their repertoire of relevant exercises to enhance physical preparation for sprinting. Ultimately, the key to improving sprint performance lies in the consistent incorporation of resistance training exercises specifically designed to meet the unique needs of sprinters (Young, Benton, Duthie, & Pryor, 2001.)

Muscles that are needed for sprinting include the quadriceps, gluteals, hamstrings, calves, hip flexors, and various muscles in the pelvic and trunk region for stability. In short sprints, the quadriceps are relatively more important, while the hip extensors, such as the gluteals and hamstrings, are relatively more important for faster sprints. The plantar flexors of the ankle (calf muscles) and hip flexors are also crucial for sprinting. Additionally, exercises that target the gluteal and hamstring muscle groups, such as the Romanian deadlift, are more specific to maximum-speed sprinting. Muscles that contribute to key actions during sprinting include the knee extensors for forward propulsion, hip extensors for horizontal propulsion, and the hip flexors for leg recovery and stride frequency. In terms of strength qualities, explosive force qualities are important for all types of sprints, with various tests of power correlating higher with longer sprints or maximum speed sprints (Young, Benton, Duthie, & Pryor, 2001.)

As mentioned in the last part above on how important stride length and frequency is, one study from the Physical Education Study Program at STKIP Pasundan Cimahi addresses that resistance training can indeed improve both stride length and frequency in sprinters. By engaging in resistance training exercises that target the muscles involved in running, such as the quadriceps, hamstrings, and glutes, athletes can increase their strength, power, and overall muscle function (Abdurrahman, Lowry, Sebayang, & Ramadhan, 2022.)

According to research, exercises that increase stride length can also significantly increase leg strength, indirectly contributing to an increase in running speed. Additionally, the training load received by the leg muscles during stride length exercises is heavier than that received during stride frequency exercises, requiring more strength to overcome the training load (Abdurrahman, Lowry, Sebayang, & Ramadhan, 2022.)

Resistance training specifically helps to improve muscle strength and power, which are necessary for generating force during each stride. This increased strength can lead to longer and more powerful strides, ultimately improving stride length (Abdurrahman, Lowry, Sebayang, & Ramadhan, 2022.)

In conclusion, resistance training can improve both stride length and frequency by enhancing muscle strength, power, and overall muscle function, all of which are essential for optimal running performance (Abdurrahman, Lowry, Sebayang, & Ramadhan, 2022).

In addressing the theoretical underpinnings of an off-season training program, a study conducted at the University of Limerick, Ireland, provides invaluable insights. This study interviewed seven expert track and field sprint coaches to investigate their perspectives on resistance-based training for sprinting. The interviews were semi-structured and lasted around forty-five minutes each, conducted at a location chosen by the coaches. The study aimed to bridge the gap between researchers and practitioners in resistance-based training for sprinting, offering insights into coaches' practices and rationale. Ethical approval was obtained, and informed consent was acquired from each coach. The study sought to explore the types of resistance exercises used by competitive sprinters, the reasoning behind coaches' choices, and how they implemented and controlled them in training.

During the off-season, sprinters typically focus on building strength and endurance as part of their training program. Coaches often emphasize a strength focus on the initial part of the season, gradually transitioning to more dynamic and sport-specific exercises as competition approaches. Common resistance-based training exercises used during the off-season include variations of squats, Olympic weightlifting movements, deadlifts, plyometrics, and resisted running using weighted jackets, hill running, and weighted sleds. Coaches may also incorporate plyometric exercises such as bounding, depth jumps, and ankle hops to improve sprinting technique and performance. The selection of exercises during the off-season is based on the coaches’ experience and the specific needs of the athletes, with a focus on developing a solid strength and aerobic base for optimal performance (Bolger, Lyon & Harrison, 2016.)

Programming of training during the on-season the annual training plan in athletics (i.e. sprint running) usually consists a bicycle periodization model, where competing occurs in two phases: indoor and outdoor. Programming is used to direct training progressively throughout the subsequent phases, to stimulate physiological adaptations, manage fatigue and to optimize peak performance to occur in main competitions. Furthermore, training should not occur in a linear fashion, but it must be alternated with the volume and intensity of training and with respect to the individual necessities of the sprinter. The most common microcycle rhythm is 2:1 -cycle, where two weeks of high training load entitles one week of rest and recovery associated with a lower training load. Certainly, also other similar versions can be programmed. The number of races during the competitive phases determines the cycling of training load. Annually, the total number of races varies from 20 to 30 among elite sprinters. The average number of training within a microcycle varies distinctly across different season phases. During a preparatory phase, a microcycle may consist of five sessions of high load and additional five of preparative- or restorative sessions. While approaching competitions the quantity of sessions decreases significantly (Mero, 2020.)

The first transition phase begins immediately after the indoor competition phase is finished. Due to the long preparative- and competition phases that have included intense training and performance outputs, a sprinter is put under a large amount of cumulative fatigue and physiological stress. If this stress is applied for too long overtraining may occur, consequently decreasing performance capacity. Therefore, the transition phase is used for recovery and regeneration from the competition phase and is featured with a period of unloading that lasts a week. This will allow the sprinter to prepare for training in the second preparatory phase. Some practitioners may not use transition phase after the competitive phase I at all (Mero, 2020.)

Competition phase II (i.e. outdoor season) is the second competitive phase of the annual season and often identified as the more important one. Outdoor season lasts approximately for 31/2 months. Especially, development of maximal velocity and sprint specific endurance are attained during the outdoor season. Similarly, to the indoor season training volume is reduced distinctly during outdoor season and is replaced with elevation of training intensity and peaking. The objective of training during competition phase is to induce optimal physiological adaptations at optimal times to consequently maximize performance at sprint races. Competitions are often arranged progressively in order of their importance and challenge (i.e. high performing peers), while also utilizing different events (e.g. 200-meter sprint) for performance optimization that lead to success in the main competitions. Therefore, in some cases, the outdoor season may be subdivided into early and late peaks in order to prepare for national trials and international championships. Early and late peaking may be dissociated with a brief preparatory period to enable the ultimate peak in performance to be reached at the main competitions. Some sprinters compete less than others and seek speed development through intense training while others use competitions as practice, yet in general minimum of 2–3 sprint races are needed to elevate performance up to personal standards (Mero, 2020). Annually, the total number of races vary from 20 to 30 among elite sprinters. (Mero, 2020)

4.2 Exercises for resistance training

Strength training is a type of exercise that focuses on increasing the maximal force or power that muscles can generate. This type of training typically involves lifting heavier weights for fewer repetitions in order to build muscle strength and overall physical strength. On the other hand, hypertrophy training is a form of resistance training that aims to increase muscle size through the enlargement of muscle cells. This type of training involves moderate to high repetitions with lighter to moderate weights, with a focus on muscle endurance and volume (Moesgaard, Christiansen, Beck, Aagaard, Lundbye-Jensen, 2022.)

Specifically, strength training is characterized by sets of low repetitions (e.g. 1-6 reps) with high intensity (often defined as a percentage of one's one-rep max) and longer rest periods between sets. This type of training is typically used to improve maximal strength and power output in ind 8ividuals. In contrast, hypertrophy training involves sets of higher repetitions (e.g. 6-12 or more reps) with moderate intensity and shorter rest periods. The goal of hypertrophy training is to stimulate muscle growth and increase muscle mass, often leading to a more aesthetically pleasing physique (Moesgaard, Christiansen, Beck, Aagaard & Lundbye-Jensen, 2022.)

Hypertrophy & Strength variation of exercises:

Squat - Enhancing sprinting performance by increasing leg stiffness and reducing ground contact time (Comyns, Harrison & Hennessy, 2010). The squat exercise can have a positive impact on speed by improving lower-body strength, which is crucial for force development during sprinting. The back squat specifically engages the muscles of the hip and knee flexors and extensors, including the vastus muscles, gluteus maximus, and hamstrings. Studies have shown a correlation between squat strength and sprint performance, with higher absolute and relative squat strength associated with faster sprint times. By progressively increasing squat loads and incorporating the exercise into a structured training program, athletes can build a foundation of strength that can enhance sprint acceleration. Additionally, power, which is essential for sprint performance, is dependent on strength, making the squat exercise valuable for improving both strength and speed. (Robert, 2017)

Hip Thrust - Research suggests that the hip thrust may offer an advantage in developing sprinting speed over traditional exercises like the back squat and deadlift. This is because the hip thrust emphasizes full hip extension, which is crucial for improving sprinting speed, jumping, and lateral movement speed. The horizontal loading pattern of the hip thrust may have greater carryover to sprinting speed due to horizontal force application and its relationship to faster sprinting speeds. Additionally, hip thrust activates high levels of gluteal muscles, which are essential for hip extension and contribute to faster sprinting speeds. (Zweifel, 2015)

Deadlift - A meta-analysis by Seitz et al. (2014) demonstrated that strength in the back squat, which could be analogous to strength gained from deadlift training, significantly correlated with sprinting speed (Zweifel, 2015).

Cable hip flexion - This movement-specific exercise targets the hip flexor muscle group, which is crucial for increasing step frequency and lengthening step during sprinting. Studies have suggested that greater hip flexion can aid in improving running speed by enhancing step length and frequency. Specific hip flexor training has been found to increase hip flexor strength and improve sprint and shuttle run times in athletes. Additionally, incorporating unilateral exercises like cable hip flexion in a strength training program for speed development has been recommended to enhance sprint performance. By including cable hip flexion in a structured training program, athletes can potentially improve their sprint acceleration through increased hip flexor (Robert, 2017.)

Step-ups - Step-ups have a positive impact on speed performance by targeting the muscles involved in hip extension, which is essential for sprinting acceleration. The exercise places significant stress on the hip extensors, which are crucial for optimal acceleration performance. Strong extension of the support leg is recommended for accelerating effectively, and hip extensors are identified as prime movers for acceleration. Additionally, the hamstrings play a role in movements like the loaded step-up, emphasizing the importance of eccentric hamstring strength to prevent injuries during maximal sprinting (Robert, 2017.)

Nordic hamstring curls – incorporating Nordic hamstring exercise (NHE), into training regimens offers significant benefits for sprinting performance. These benefits include improved sprint times, particularly over short distances, enhanced eccentric knee flexor strength, and reduced risk of hamstring injuries due to structural adaptations like increased muscle fascicle length. Additionally, the NHE improves overall physical performance in team sports, making it a valuable exercise for athletes who require rapid and frequent changes in movement (Bautista, Vicente-Mampel, Baraja-Vegas, Segarra, Martín & Van Hooren, 2021.)

Standing calf raise - The muscles around the ankle are important for force attenuation during stance and power generation during takeoff. By strengthening the calves through standing calf raises, athletes can improve their ability to absorb and propagate force during sprinting. This exercise can help enhance the force-velocity relationship, a key factor in sprint acceleration (Robert, 2017.)

Power variation of exercises:

Weighted jump squats - Studies have shown that heavy load ballistic training can lead to improvements in sprint ability, likely due to increases in strength, rate of motor unit recruitment, activation of type II muscle fibers, and improvements in maximum force capabilities at zero velocity. On the other hand, light load ballistic training allows athletes to train at speeds similar to on-field tasks, which can enhance neural activation rates, inter-muscular coordination, and maximum velocity capabilities. These training methods follow the principle of specificity, where adaptations are greatest at or around the loads, velocities, and movement patterns utilized during training (McMaster, Gill, McGuigan & Cronin, 2014.)

Power/hang cleans - through the power clean exercise, athletes can develop their ability to generate force rapidly and efficiently, translating into faster acceleration and sprinting speeds. Specifically, the power clean targets the muscles involved in sprinting, such as the quadriceps, hamstrings, glutes, and calves, which are crucial for propelling the body forward with strength and speed (McMaster, Gill, McGuigan & Cronin, 2014.)

Snatch – The movement involves great acceleration of the segments through the entire movement resulting in mobilization of the barbell at high velocities, has been shown to have a positive impact on sprinting performance. One of the key reasons for this improvement is the changes in the stretch-shortening cycle pattern and increases in the muscle-tendon unit's stiffness that occur after weightlifting training. This increase in muscle-tendon unit stiffness is crucial for enhancing lower-limb performance, which is essential for sprinting (García-Valverde, Manresa-Rocamora, Hernández-Davó & Sabido, 2021.)

Bulgarian Split Squats - The Bulgarian split squat exercise has notable benefits for sprinting, primarily by enhancing lower body strength, balance, and coordination. This unilateral exercise targets key muscle groups involved in sprinting, such as the quadriceps, hamstrings, glutes, and calves, improving their power and stability. By strengthening these muscles, athletes can generate greater force and maintain better control during each stride, contributing to faster acceleration and overall sprint performance. Additionally, the exercise can enhance hip flexibility and mobility, crucial for optimal sprinting mechanics. Although some studies suggest mixed results regarding its immediate impact on sprint speed, particularly in untrained individuals, the consensus indicates that with proper training and application, the Bulgarian split squat can be a valuable component of a sprinter's strength training regimen (Dinç & Hayta, 2021.)

Training the upper body is an important component of sprint training as it helps to improve overall strength and power, which can directly impact sprinting performance. When it comes to sprinting, proper running mechanics and technique are crucial for maximizing speed and efficiency. Strengthening the upper body through exercises such as bench presses, arm curls, and stomach curls can help sprinters develop the necessary strength and stability to maintain proper posture and arm movement while sprinting (Baughman, Takaha & Tellez, 1984.)

Additionally, incorporating upper body training into a sprinter's regimen can help in preventing muscle imbalances. This is important as having balanced strength in the upper body can contribute to overall body alignment and coordination during the sprinting motion (Baughman, Takaha & Tellez, 1984.)

Moreover, maintaining maximum velocity during sprinting requires good form and mechanics, which can be supported by a strong upper body. This is because proper alignment of the head and trunk, as well as arm movement during sprinting, can be enhanced through upper body strength training (Baughman, Takaha & Tellez, 1984.)

In conclusion, incorporating upper body training into a sprinter's workout routine can have a significant impact on sprinting performance by improving overall strength, stability, and body alignment during the sprinting motion (Baughman, Takaha & Tellez, 1984).

Upper-body exercises:

Bench Press - The bench press is a great exercise to develop upper body strength, specifically targeting the chest, shoulders, and triceps. It is crucial for sprinters to have a strong upper body to maintain proper running form and power during sprints (Baughman, Takaha & Tellez, 1984.)

Arm Curls: Arm curls isolate the biceps and help improve arm strength, which is important for generating power and speed during sprints (Baughman, Takaha & Tellez, 1984).

One arm dumbbell rows – are strength exercises that can contribute to overall upper body strength gains, which may in turn enhance force generating capabilities and subsequently improve sprint performance (McMaster, Gill, McGuigan & Cronin, 2014).

Stomach Curls: Stomach curls target the core muscles, including the abdominals and obliques, which are crucial for maintaining stability and balance while sprinting (Baughman, Takaha & Tellez, 1984).

Bent Knee Sit-Ups: Bent knee sit-ups are effective for strengthening the core muscles and improving overall endurance, which can contribute to enhanced sprinting performance (Baughman, Takaha & Tellez, 1984).

Table 1. Recommendations for maximal strength, power, and endurance strength training. (Enroth, 2020)

Method	**Load (%/1RM)**	**Repetitions/set**	**Preferred implementation**
Maximal strength			
Neural	90–100	1–3	Weight room
Hypertrophic & neural	70–90	3–6	Weight room
Hypertrophic	60–80	6–12	Weight room
Power			
Neural	30–60	1–10	Weight room, plyometrics with added weight
Hypertrophic & neural	30–80	1–10	Weight room, plyometrics with added weight
Endurance strength			
Anaerobic	20–60	10–30	Weight room, circuit training
Aerobic	0–30	>30	Circuit training

Overload

In planning and implementing strength-power training programs for track and field athletes, it is essential to carefully manage the progression of load increases over weeks to avoid potential negative outcomes such as overtraining or injury. Research suggests that heavy and light days within a microcycle can be an effective strategy to vary training loads and manage fatigue. By incorporating variations in volume and intensity, athletes can optimize recovery from intense training sessions and prevent accumulated fatigue (DeWeese, Hornsby, Stone & Stone, 2015.)

When increasing the load over weeks, it is important to consider individual athlete characteristics, exercise type, set/repetitions scheme, and fatigue levels. Using a percentage range based on 1RM can help tailor the load to the specific needs of the athlete and prevent potential problems associated with accumulative fatigue. A sequential training protocol can guide the progression, starting with increasing cross-sectional area (hypertrophy), followed by central effects and force production enhancement, and completing with the development of power output (DeWeese, Hornsby, Stone & Stone, 2015.)

Additionally, monitoring the athlete's current training state, fatigue levels, and responses to the program through a monitoring/testing program can provide valuable insights for adjusting load progression. Implementing programs that consider differences in trained states and understanding that maximum effort is necessary for neuromuscular system development can also contribute to optimizing load increases over weeks (DeWeese, Hornsby, Stone & Stone, 2015.)

In summary, when increasing the load over weeks in strength-power training programs for track and field athletes, coaches and athletes should carefully consider individual factors, vary training loads through heavy and light days, monitor athlete responses, and prioritize maximum effort to support optimal development and performance adaptations (DeWeese, Hornsby, Stone & Stone, 2015.)

4.3 Recovery

There is a wide variety of different recovery interventions and modalities that can be used during the different phases of training and competing. Each of the modalities, either pre-interor post exercise and long-term recovery strategies are used to maximize training outcomes. Post-exercise recovery is commenced after the training session is finished and is related to the removal of metabolic by-products, the replenishment of energy stores and anabolic processes (e.g. tissue repair). Meaning that the body does not immediately return to a resting state after the cessation of training. In addition to a careful planning of a taper long-term adaptations can be evoked with a well periodized annual training plan where long-term recovery is considered with detail, thus resulting in a supercompensation effect.

Recovery is a complex multifactorial process where it is beneficial to understand the psychological and physiological mechanism that affects recovery. Furthermore, it is essential to understand the inter-individual differences and preferences of, especially our own sprinters. Generally, recovery is affected by factors such as age, training status, gender, time zone shifts and nutrition. The propriate recovery strategies alter over the phases of annual training and therefore practitioners should be familiar with concepts that can be applied to enhance recovery. Although, much scientific research has been conducted around all the following recovery modalities this chapter's objective is only to introduce the reader to the variety of recovery interventions.

According to Enroth (2020) Bompa & Buzzichelli (2018) the most natural form of recovery is passive recovery performed by sleeping. The sprinter must always be ensured with adequate nighttime sleep. Many of the literature suggests that sleep for 8 to 10 hours is referred to be adequate for an elite athlete, from which 80–90 % should occur at nighttime (i.e. both REM and NREM), while the remaining may be made up with naps (i.e. light sleep). Among elite sprinters, sleeping rhythms may be disturbed during competitive season if the traveling requires crossing multiple time zones. It needs to be noted that it usually takes between 2–3 days for sleep quality to return to normal, 3–5 days for jet lag symptoms to dissipate and 6–8 days for performance variables to return to normal.

The sprinter must be prepared with an individual recovery plan for competitions at different time zones. In contrast to the characteristics of passive recovery, active functions can also be undertaken to enhance recovery. Post exercise active recovery is commonly initiated with a warm-down routine of light exercise. This seems to be more efficient in augmenting recovery compared to remaining passive immediately after the exercise. Active recovery is found to be beneficial since it increases the rate of lactate clearance significantly, allows a more gradual body temperature decline, dampening of the central nervous system activity and reduces the perceived degree of exercise-induced muscle soreness and/or delayed onset muscle soreness (DOMS). The most noted effects of an active recovery seem to be performed at intensities of <50 % of VO2 max (Enroth, 2020.)

Active recovery may also include stretching and other muscle care exercises. Another commonly used method of recovery enhancement is massage therapy. Massage therapy is exploited throughout the training year as well as during competitive phases, with slightly different approaches. Massage can be undertaken both prior to training or competition (i.e. preparatory massage) and after it (i.e. restorative massage). Optimal times for massages need to be implemented as part of the recovery plan. It seems that a combination of active recovery techniques, followed by massage and completed with passive rest is superior compared to only one recovery technique (Enroth, 2020.)

Other recovery strategies may include thermotherapy (e.g. sauna, hot water immersion), cryotherapy (e.g. cold-water immersion, ice massage) or a combination of these to (i.e. contrast therapy). Thermotherapy is performed as an intention to increase body temperature by techniques such as sauna, hot water immersion, steam bath, warm whirlpool, hydrocollator packs, paraffin baths and infrared lamps or rooms. Whereas cryotherapy includes techniques such as cold-water immersion, ice bath, ice massage or usage of ice packs for treating acute traumatic injury and facilitating recovery. Contrast therapy is a combination of the two mentioned techniques, where heat and coldness are alternated to induce a “muscle pumping” - like action as a result of the alternation between vasodilation and vasoconstriction. Most common form of contrast therapy is hot-cold water immersion. In some literature water immersions may be referred to as hydrotherapy. In addition to hot and cold-water immersion, hydrotherapy can be also performed with thermoneutral water temperatures of 16–35 °C. The beneficial effects of hydrotherapy are hypothesized to occur as a function of the hydrostatic pressure that it created towards the body when immersed in water. Hydrostatic pressure stimulates the displacement of fluids away from the extremities and towards the central cavity of the body. Therefore, water immersion could theoretically provide similar effects to those of active recovery, by increase cardiac output that increases blood flow (Enroth, 2020.)

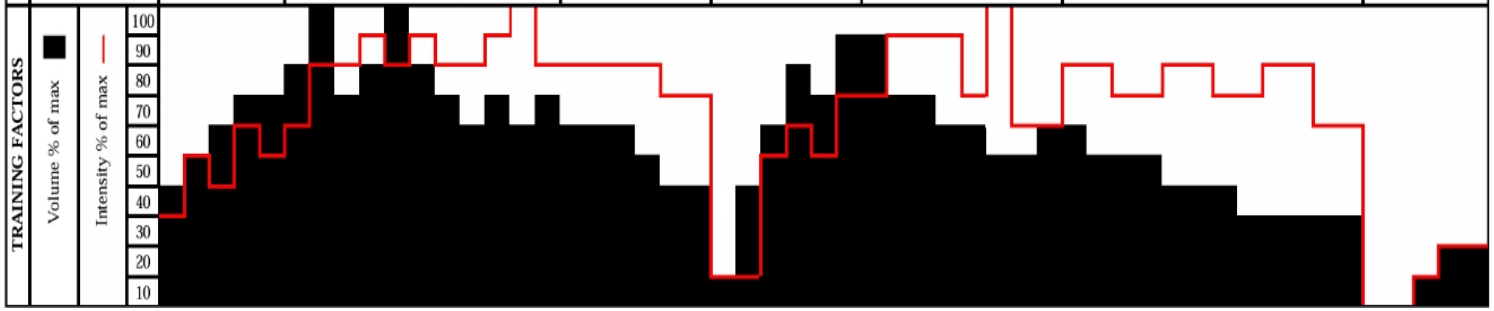
Some may also use compression garments for promoting blood flow. Furthermore, recovery can be enhanced with nonsteroidal anti-inflammatory drugs and nutritional strategies that are discussed in chapter. Altogether a combination of different strategies is believed to be most beneficial for inducing recovery. As briefly mentioned, there are variety of recovery strategies available, ranging from passive rest to special modalities that are designed to enhance and speed up the recovery process. Appropriate combination of interventions appears to result in most rapid rates of recovery. Although further research is needed to elucidate the optimal combination and sequencing of these methods. As well as the inter-individual preferences always need to be considered by the sprinter and the practitioners, based on the sprinter’s tolerance and response to the different modalities. A wide scientific database is available for studying the optimal apply and usage of the before mentioned recovery strategies along with researched information about the underlying mechanisms and physiological adaptation (Enroth, 2020.)

5 Annual periodization

The yearly plan spans 12 months and is designed to systematically guide training, enhancing physiological and psychological adaptations, managing fatigue, and ensuring peak performance at crucial times while prioritizing recovery through factors like nutrition and sleep. Rather than following a linear progression, training is organized into smaller, distinct segments known as training phases, employing periodization to target various training forms with specific objectives. Effective periodization not only boosts sprint performance but also safeguards against excessive stress, overtraining, and performance decline by integrating periods of recovery and regeneration. Long-term performance gains necessitate a methodical increase in training load over time, balanced with adequate recovery. This approach considers the sprinter's bio motor abilities, readiness level, psychological traits, and fatigue management, ensuring the capacity to handle training loads effectively. Given the multifaceted nature of training, the annual plan is structured into logical sequences of training phases tailored to individual needs, incorporating appropriate volumes and intensities, realistic goals, and flexibility for adjustments. These phases aim to progressively develop physiological, technical, and psychological components of sprint performance. The annual plan typically consists of two main cycles, analogous to bicycle pedals—one focused on indoor competitions and the other on outdoor events, with each cycle comprising preparatory, competitive, and transition phases. Each phase is further divided into micro cycles (e.g., weekly training plans) and macrocycles (e.g., several weeks of training), allowing for adjustments in volume and intensity. The duration of each phase is determined by the time required to enhance specific performance components and elevate overall training status and readiness, with the competition schedule serving as a primary determinant, ensuring peak performance alignment with key events. The phases of a bicycle annual sprint training plan are generally as follows: preparatory phase I, competitive phase I (i.e. indoor), transition phase I, preparatory phase II, competition phase II (i.e. outdoor) and transition phase II (see TABLE 2) (Enroth, 2020.)

TABLE 2: Bi-cycle annual training plan in sprint training (Enroth, 2020).

<table>
<tr><td colspan="2">MONTH</td><td colspan="5">1</td><td colspan="4">2</td><td colspan="4">3</td><td colspan="5">4</td><td colspan="4">5</td><td colspan="4">6</td><td colspan="5">7</td><td colspan="4">8</td><td colspan="4">9</td><td colspan="5">10</td><td colspan="4">11</td><td colspan="5">12</td></tr>
<tr><td colspan="2">WEEK</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td>26</td><td>27</td><td>28</td><td>29</td><td>30</td><td>31</td><td>32</td><td>33</td><td>34</td><td>35</td><td>36</td><td>37</td><td>38</td><td>39</td><td>40</td><td>41</td><td>42</td><td>43</td><td>44</td><td>45</td><td>46</td><td>47</td><td>48</td><td>49</td><td>50</td><td>51</td><td>52</td><td>53</td></tr>
<tr><td colspan="2">Competition</td><td colspan="16"></td><td>X</td><td>X</td><td colspan="2"></td><td>X</td><td>X</td><td colspan="14"></td><td>X</td><td></td><td>X</td><td>X</td><td colspan="2"></td><td>X</td><td>X</td><td colspan="2"></td><td>X</td><td>X</td><td colspan="5"></td></tr>
<tr><td colspan="2">Testing</td><td>X</td><td colspan="9"></td><td>X</td><td colspan="3"></td><td>X</td><td colspan="8"></td><td>X</td><td colspan="9"></td><td>X</td><td colspan="19"></td></tr>
<tr><td rowspan="3">PERIODIZATION</td><td>PHASE</td><td colspan="12">PREPARATORY I</td><td colspan="10">COMPETITIVE II (INDOOR)</td><td rowspan="2">TRANSITION I</td><td colspan="10">PREPARATORY II</td><td colspan="15">COMPETITIVE II (OUTDOOR)</td><td colspan="5" rowspan="2">TRANSITION II</td></tr>
<tr><td>SUBPHASE</td><td colspan="5">GENERAL PREPARATION</td><td colspan="6">SPESIFIC PREPARATION</td><td colspan="5">PRE COMPETITION</td><td colspan="6">OFFICIAL COMPETITION</td><td colspan="3">GENERA L PREP.</td><td colspan="7">SPESIFIC PREPARATION</td><td colspan="3">PRE COMPET ITION</td><td colspan="12">OFFICIAL COMPETITION</td></tr>
<tr><td>OBJECTIVE</td><td colspan="5">Construct strong physiological base, improve trainability</td><td colspan="6">Transition to sprint-specific modalities</td><td colspan="5">Elevating performance</td><td colspan="6">Peak perfromance</td><td>Rest</td><td colspan="3">Maximazin g strength levels</td><td colspan="7">Transition to sprint-specific modalities</td><td colspan="3">Maximizin gperforma nce</td><td colspan="12">Peak perfromance at major competitions</td><td colspan="5">Full recovery and regeneration</td></tr>
<tr><td rowspan="4">EMPHASIS</td><td>Sprint training</td><td colspan="5">Technical, tempo</td><td colspan="5">Accel., resisted sprints, speed end.</td><td colspan="5">Acceleration, max velocity</td><td colspan="7">Max velocity, assisted sprints</td><td colspan="5">Technical, tempo</td><td colspan="8">Max velocity, sprint spesific endurance</td><td colspan="13">Max velocity, assisted sprints, sprint-spesific endurance</td><td colspan="5">Off</td></tr>
<tr><td>Strenght training</td><td colspan="4">Hypertrophy</td><td colspan="6">Maximal strength and sprint spesifics</td><td colspan="6">Power</td><td colspan="6">Maintenance</td><td colspan="6">Maximal strength</td><td colspan="8">Power</td><td colspan="12">Mainteinance</td><td colspan="5">Off</td></tr>
<tr><td>Other training</td><td colspan="5">Comprehensive overall</td><td colspan="5">Aerobic-anaerobic,</td><td colspan="5">Anaerobic lactic</td><td colspan="7">Anaerobic alactic, plyometrics</td><td colspan="5">Aerobic, upper body and mobility</td><td colspan="8">Plyometrics</td><td colspan="13">Anaerobic alactic</td><td colspan="5">Diverse</td></tr>
<tr><td>Nutrition</td><td colspan="5">Balanced</td><td colspan="11">Protein and carbohydrates</td><td colspan="6">High on carbohydrates</td><td colspan="6">Balanced</td><td colspan="8">Protein and carbohydrates</td><td colspan="12">High on carbohydrates</td><td colspan="5">Balanced</td></tr>
</table>



5.1 Preparatory phase I

Preparatory Phase I commences following the conclusion of the previous competitive season and the subsequent transition period between the annual seasons. Typically spanning around three months, this phase is often divided into general and specific preparatory stages. The general preparatory phase focuses on establishing a robust physiological foundation to withstand extensive training loads, broadening the sprinter's capacity for the upcoming season, and facilitating adaptation to the intensification of training during the competitive phase. It also serves as an opportunity for extended recovery, rehabilitation, and addressing any deficiencies, such as mobility issues. Additionally, the preparatory phase is conducive to overall conditioning, core strength development, and addressing muscular imbalances, particularly in the upper body. During the initial stages of the general preparatory phase, a significant volume of sprint training is conducted at low intensities, emphasizing aerobic and anaerobic endurance. This gradual introduction to high-volume training is followed by a rapid escalation in training quantity. Intensity gradually increases throughout the preparatory phase, with a shift towards predominantly anaerobic training modalities. Exercises like resisted sprints and hill sprints are commonly integrated into training during this phase. Strength training initially focuses on hypertrophy and maximal strength, with an emphasis on vertical movements. The high volume of training in the general preparatory phase also serves psychological purposes, fostering determination and perseverance essential for elite sprinters (Enroth, 2020.)

In the specific preparatory phase, training volume remains high while intensities continue to rise. Emphasis shifts towards sprint-specific modalities aimed at developing the characteristics required for a 100-meter sprint. This includes biomechanically similar movements in strength training, coordination and technique exercises, and the incorporation of horizontally directed movements to facilitate the transition from vertical strength to sprinting power. Power training accompanies strength training, while sprint training progresses from acceleration work to maximal velocity running and sprint-specific endurance during the pre-competition phase. As the competitive phase approaches, training volume may decrease by up to 40%, with a focus on explosive strength and plyometrics. The specific preparatory subphase typically constitutes 75–85% of the entire preparatory phase. It's noted that a significant portion of hamstring injuries among competitive sprinters occur during the transition from the specific preparatory phase to the competitive phase. While this transition period involves a reduction in training volume and an increase in intensity, it's crucial for sprinters to gradually mobilize their maximal sprinting capacity to minimize injury risk. Balancing training speed with competition speed is essential to mitigate the risk of injury and overtraining, while adhering to the principle of progressive overload to stimulate long-term training adaptations (Enroth, 2020.)

TABLE 3: An example of a seven-day microcycle of high training load during the preparatory phase I (Enroth, 2020).

DAY	MORNING	AFTERNOON
1	Rest	Rest
2	Running technique	Maximum strength
3	Circuit training + tempo	Hill + plyometrics
4	Rest	Body care + mobility
5	Speed	Hypertrophy
6	Rest	Mobility
7	Aerobic endurance + hill	Rest

5.2 Competitive phase I

In a cycling-based training plan, the competition phase I, also known as the indoor season, marks the initial competitive period in the annual training schedule. This phase typically spans around 2 and a half months, during which the sprinter's performance needs to reach its peak. The competitive phase is typically divided into pre-competition and official competition stages. The pre-competition phase may coincide partially with the latter part of the specific preparatory phase, as training focuses on similar objectives, and the transition from training speed to competition speed must be gradual (Enroth, 2020.)

The peaking process begins gradually during the specific preparatory and pre-competition phases, characterized by a distinct reduction in training volume and an increase in training intensity. Training volume is often decreased by 25 to 50% compared to the preparatory phase. The highest training intensities are typically reached two or three weeks before the main competition. It's advisable not to engage in maximal intensity training more than two or three times a week during the competition phase. During the early stages of the competition phase, performance is not pushed to its extreme peak; instead, the focus is on preserving performance capacity. Initial competitions serve as practice and testing opportunities for the major indoor competitions held towards the end of the competition phase. For 100-meter sprinters, the 60-meter sprint event often takes precedence during the indoor season. A tapering or unloading period, typically lasting one or two microcycles (around 8 to 14 days), is often implemented just before competitions to optimize performance. Achieving peak performance is the primary challenge of successful periodization in sprint training (Enroth, 2020.)

TABLE 4: An example of a seven-day microcycle of high training load during the competitive phase I (Enroth, 2020).

DAY	MORNING	AFTERNOON
1	Rest	Rest
2	Body care	Block start + acceleration
3	Speed endurance	Rest
4	Power (short)	Rest
5	Light preparative exercise	Rest
6	Competition	Competition
7	Competition	Competition

5.3 Transition phase I

Following the conclusion of the indoor competition phase, the initial transition phase commences immediately. The preceding preparatory and competitive phases involve rigorous training and high-performance demands, resulting in significant cumulative fatigue and physiological stress for sprinters. Prolonged exposure to such stress can lead to overtraining, ultimately impairing performance capacity. Hence, the transition phase serves as a period of recovery and rejuvenation following the intense competition phase. It includes a week-long period of unloading, allowing sprinters to recuperate effectively before embarking on the second preparatory phase of training. It's noteworthy that some practitioners may opt not to incorporate a transition phase following the first competitive phase at all (Enroth, 2020.)

5.4 Preparatory phase II

Preparatory Phase II is typically briefer compared to the initial Preparatory Phase I, spanning around 2 months. The shorter duration of Preparatory Phase II is often justified by the sufficient physiological foundation established during the first phase, allowing training to progress with higher volumes and intensities without the need for extensive familiarization. As a result, Preparatory Phase II primarily consists of a brief general preparatory subphase, with the majority of training focused on the specific preparatory subphase (Enroth, 2020.)

TABLE 5: An example of a seven-day microcycle of high training load during the preparatory phase II. (Enroth, 2020)

DAY	MORNING	AFTERNOON
1	Rest	Rest
2	Mobility + core strength	Acceleration + circuit training
3	Tempo	Maximal strength
4	Rest	Body care
5	Submaximal speed	Maximal strength
6	Rest	Tempo
7	Rest	Rest

5.5 Competitive phase II

Competition Phase II, also known as the outdoor season, constitutes the second competitive phase of the annual athletic calendar and is often regarded as the more significant one. Spanning approximately 3 and a half months, the outdoor season focuses notably on enhancing maximal velocity and sprint-specific endurance. Similar to the indoor season, training volume is markedly reduced during the outdoor season, with a corresponding increase in training intensity and peaking efforts. The primary objective of training during the competition phase is to elicit optimal physiological adaptations at strategic times, thereby maximizing performance in sprint races. Competitions are typically organized in a progressive manner based on their significance and level of challenge, often incorporating various events such as the 200-meter sprint to optimize performance leading up to major competitions. Consequently, the outdoor season may sometimes be subdivided into early and late peak periods to adequately prepare for national trials and international championships. These peak periods may be preceded by brief preparatory periods to ensure peak performance is achieved during the main competitions. Sprinters vary in their competition frequency, with some opting for intense training to develop speed, while others use competitions primarily for practice. However, generally, a minimum of 2 to 3 sprint races are required to enhance performance to personal standards. Elite sprinters typically participate in anywhere from 20 to 30 races annually (Enroth, 2020.)

TABLE 6: An example of a seven-day microcycle of high training load during the outdoor season. (Enroth, 2020)

DAY	MORNING	AFTERNOON
1	Rest	Rest
2	Block start + acceleration	Power
3	Rest	Light exercise + body care/massage
4	Power (short)	Rest
5	Rest	Rest
6	Competition	Competition
7	Competition	Competition

5.6 Transition phase II

Transition Phase II, also known as the compensation phase, marks the conclusion of the annual training plan and serves as a bridge to the next season. Its primary goal is to alleviate physiological and psychological fatigue, enable full athlete recovery, promote regeneration, and prepare for the upcoming season. For athletes recovering from injuries, this phase facilitates rehabilitation and restoration of movement capacity. These objectives are achieved through unloading and the implementation of active rest. Regardless of injury status, all sprinters should incorporate periods of active rest into their routines. Additionally, mild resistance training, exercises targeting weaknesses (such as mobility issues), stabilization exercises for muscle groups, and other unconventional forms of exercise should be considered. During this phase, all training loads are reduced, with a focus on general training and minimal technical development (Enroth, 2020.)

Typically, maintaining approximately 40–50% of the training volume from the competitive phase is considered adequate for general physical preparation during the transition phase. Active rest promotes physiological and psychological recovery, broadens the athlete's base for trainability, and reduces the risk of potential injuries. However, it's important to note that a total cessation of training (i.e., training pause) is not advisable, as it may lead to a significant decrease in performance. Transition Phase II may extend up to one month before the initiation of the next annual training plan (Enroth, 2020.)

5.7 Tapering

Tapering in sprint training is a crucial aspect that involves reducing the training load prior to a competition to ensure peak performance. It is a progressive non-linear reduction of training load during a predetermined time, aimed at systematically reducing physiological and psychological cumulative fatigue. Tapering involves reducing training volume by 40% to 50% in the first microcycle, with variations based on the level of training undertaken before the taper. The duration of tapering usually lasts between 8 to 14 days, covering two microcycles, depending on the type of training and individual sprinter (Enroth, 2020.)

During tapering, the main goal is to reduce accumulated fatigue from previous training and competitions while maintaining or slightly increasing training intensity. The reduction in training volume is accompanied by maintaining or slightly increasing training intensity to avoid detraining. In the second microcycle of tapering, further reductions in training volume and intensity are made before the competition to maximize performance gains. This may involve multiple peaks with the final peak occurring at the competition itself (Miro, 2020).

Strength training is also adjusted during tapering, with reductions in volume and frequency while maintaining moderate to high intensities to preserve strength levels. The tapering process allows for recovery and regeneration from intense training phases, thereby preventing overtraining and enhancing performance capacity (Enroth, 2020.)

Tapering is a complex process that requires careful manipulation of volume and intensity to achieve peak performance. It is an essential component of sprint training and coaching, aiming to optimize sprinter’s preparedness and performance for major competitions. Recovery during tapering is crucial and may include passive recovery methods such as adequate nighttime sleep and individualized recovery plans for competitions in different time zones. Overall, tapering plays a significant role in ensuring sprinters reach their peak performance levels at key competitions (Enroth, 2020.)

6 Research method.

The proposed method that was recommended by KAMK instructors is a light way of systematic research method to develop the product (Guidebook). To begin with, it is imperative to elucidate the concept of systematic research and comprehend its structural framework. For a comprehensive understanding, we turn to the article entitled "How to Write a Systematic Review" authored by Rick W. Wright, as published in CLINICAL ORTHOPAEDICS AND RELATED RESEARCH.

A systematic review is a comprehensive and structured form of literature review that involves the systematic assembly, critical appraisal, and synthesis of all relevant studies on a specific topic. It is a method used in evidence-based medicine to combine research evidence with clinical experience and patient needs. Systematic reviews are considered the highest form of evidence for clinicians, providing a robust summary of current evidence on a particular topic. The goal of a systematic review is to make conclusions based on the best available scientific evidence to improve clinical decision-making. This process involves formulating a research question, developing a research protocol, conducting a thorough literature search, appraising the quality of included studies, and summarizing the findings. Systematic reviews are labor-intensive and require expertise in the subject matter and review methods. They play a crucial role in elevating the standards for reviews and replacing traditional expert opinion narrative reviews with evidence-based reviews. (Wright, Brand, Dunn, & Spindler, 2007)

The strength of a systematic review is that it provides a rigorous and structured approach to summarizing all available evidence on a specific topic. By following a standardized methodology, systematic reviews minimize bias and provide a robust summary of current knowledge on a particular topic. Systematic reviews also help in clarifying the relative strengths and weaknesses of the literature, resolving conflicts, and identifying the need for further research. (Wright, Brand, Dunn, & Spindler, K. P. 2007)

On the other hand, a weakness of systematic reviews is that they can be labor-intensive and require substantial effort in terms of planning, literature search, and data extraction. Additionally, systematic reviews may suffer from weaknesses such as incomplete literature searches, missed important studies, or biases that can affect the conclusions. There may also be limitations in terms of study quality appraisal, as quality scales can be subjective and may not provide a comprehensive evaluation of individual studies. Furthermore, conducting meta-analysis in systematic reviews can be challenging, as statistical methods and assistance from a statistician are often required. It is important to carefully interpret the results of systematic reviews, considering study heterogeneity and limitations in the included studies. (Wright, Brand, Dunn & Spindler, K. P. 2007)

6.1 Research process.

According to the article entitled "How to Write a Systematic Review" authored by Rick W. Wright, a systematic review involves several key steps that are essential for conducting a thorough and unbiased assessment of existing research studies in a particular field of study. The steps of a systematic review include:

1. Formulating a Research Question: The first step is to develop a primary research question as part of a research protocol. This question should be specific, clear, and help guide the review process.

2. Literature Search: A comprehensive literature search is conducted to identify all relevant studies on the research question. This involves searching multiple databases, journals, conference proceedings, bibliographies, and unpublished studies.

3. Data Extraction: Selected studies identified during the literature search are screened, and data is extracted from them. Important information such as study design, population, intervention, outcomes, and study quality is recorded.

4. Quality Assessment: The included studies are assessed for quality using appropriate checklists or scales. This step helps identify potential biases and limitations in the studies reviewed.

5. Data Analysis and Results: The extracted data from the included studies is analyzed, summarized, and synthesized. Statistical methods may be utilized to combine results across studies.

6. Interpret Results: Finally, the results of the systematic review are interpreted, and conclusions are drawn based on the overall findings of the included studies. Recommendations for practice or further research may also be provided.

6.2 Research questions.

Research questions are specific questions that guide the focus of a research study or project. They are formulated to address a particular issue or problem and provide direction for the research process. Research questions help to define the scope of the study, identify the purpose, and determine the type of information that needs to be collected and analyzed. Different types of research questions can be formulated depending on the goals and objectives of the research project. Ultimately, research questions help researchers to structure their inquiry and guide their investigation towards finding meaningful answers (Snyder, 2019.)

6.2.1 What is the impact of strength and power training plans on the performance of teenage runners during both off and on season?

The purpose of this question is to find out the benefits of strength and power training for sprinters. To answer this question smaller questions are formed such as: what is the physiological factor of sprinting? What is biomechanic of sprinting? How does resistance training improve speed?

6.2.2 What is the difference in the program design used in on and off?

This question is essential in order to make the program, because it helps in understanding how the training program should be structured and adjusted based on the specific needs of the athletes during different phases of their training season. By identifying and addressing the differences in program design between the off-season and on-season, coaches can tailor the training regimen to optimize performance, prevent overtraining, and ensure progressive development of strength, power, and speed.

6.2.3 What are the types of recovery that should be used during the program?

Recovery plays a crucial role in optimizing athletic performance and preventing injuries. By understanding and incorporating appropriate recovery strategies, coaches and athletes can ensure that the athletes are adequately recovering between training sessions, competitions, and different phases of the program.

6.3 Material Acquisition

In a systematic literature review, materials are searched in databases and they are screened with the help of inclusion and exclusion criteria. The material was assigned the following inclusion and exclusion criteria as shown in table 6.

Table 6: Inclusion and Exclusion criteria

Include	Exclude
1) Sources between 1980-2024	1) Sources before 1980
2) English	2) Other languages
3) Free articles/books	3) Paid sources
4) Sources gathered from academic sources (E.g. Google scholar, KAMK Finna, ResearchGate, PubMed, EBSCO	4) Non-academic sources
5) Sport related sources	5) Non-sport related sources
6) Impact of strength and power training	6) Nutrition for athletes
7) Design and recovery of training	7) Technique related sources

6.4 Selection of search terms

This thesis was retrieved from academic databases such as Google Scholar, Pubmed, EBSCO and Researchgate about the literature related to “physiology”, “biomechanics”, “resistance training”, “exercises”, “strength and power training”, “sprinting”, “on and off season”, “recovery”, “safety”.

A three-stage process exclusion system was used for searching material through the databases used, where first the studies were found.

6.5 Analysis of data

The table below summarizes the collected data. Table 7 describes the content of the information search of analysis.

Table 7: Content analysis of information search

Author	Subject of research	The results of the study
Alizadeh, S., Daneshjoo, A., Zahiri, A., Anvar, S. H., Goudini, R., Hicks, J. P., Konrad, A. & Behm, D. G. (2023).	The analysis included 55 studies that specifically looked at the training effects of resistance training exercises on ROM.	The study found that resistance training significantly increases range of motion (ROM), with no difference between resistance and stretch training. Untrained and sedentary individuals showed greater ROM improvements. No differences were found based on sex, age, training duration, or frequency. Stretching before or after resistance training may not

		be necessary for improving flexibility.
Baughman, M., Takaha, M., & Tellez, T. (1984)	The subject of the research is sprint training, focusing on improving stride frequency, stride length, and anaerobic endurance to enhance an athlete's performance. The research also includes coaching concerns such as running technique, training, flexibility, racing, practice set-up, and strength training.	The research highlights the importance of proper coaching in sprint training, emphasizing stride frequency, stride length, and anaerobic endurance. Improving running technique, flexibility, strength training, and workout planning are crucial. It suggests specific exercises and training phases to enhance strength and endurance for sprinters.
Bautista, I. J., Vicente-Mampel, J., Baraja-Vegas, L., Segarra, V., Martín, F., & Van Hooren, B. (2021).	The subject of the research is the investigation of the effects of the Nordic hamstring exercise (NHE) on sprint performance and eccentric knee flexor strength in team sport players. The research analyzed a total of 15 studies. N = 419	The study concluded that the Nordic hamstring exercise (NHE) significantly improves sprint performance, particularly in short distances such as 10 meters. It also enhances eccentric knee flexor strength, which is crucial for sprinting and reduces the risk of hamstring injuries.
Bezodis, I. (2012)	The subject of the research is the relationship between velocity, step length, and step frequency in elite sprinting.	The research shows that elite sprinters rely on either step length or step frequency to maintain their speed. Training programs significantly affect

	N=4	these factors, and sprinters adjust them during sprints. The role of joint kinetics in this process is not fully understood, and more research is needed to enhance sprint performance biomechanics knowledge.
Bolger, R., Lyons, M., Harrison, A. J., & Kenny, I. C. (2016)	The subject of research is expert coaches’ perceptions of resistance-based training for sprinting. The study includes a sample of seven expert track and field sprint coaches.	The research on expert coaches' views on resistance training for sprinting found that they use various methods, such as squats, Olympic lifts, deadlifts, resisted running, hill running, and weighted sleds to enhance performance. Coaches stress the need to adapt exercises according to the training phase. The study noted a lack of research backing evidence-based resistance training for sprinters and highlighted the challenges in choosing suitable exercises. It suggests the need for better collaboration and knowledge sharing between researchers and practitioners in this field.
L. Jerome Brandon , L. J. (1995)	The sample size in the study "An assessment of	Middle distance running performance is dependent on

	performance testing in middle distance running" by Brandon, L. J. (1995) is not explicitly mentioned in the provided search results. However, in a related study on predictive performance models in long-distance runners, the sample size was not specified either	an integrative contribution from both aerobic and anaerobic variables, which allows runners to maintain a rapid velocity during races. The average VO2max for elite middle distance runners ranges between 68-77 ml/kg/min, lower than long distance runners, but they compete at a higher percentage of VO2max and incur greater energy costs per unit distance. Anaerobic threshold (ANT) relates to running velocity for distances over 5000m but not for 800m, making it less important for middle distance events compared to long distance.
Miro Enroth (2020)	The research do not mention the number of subjects or athletes included in the analysis. The study seems to be more of a review and discussion of sprint running biomechanics, technique and training programming rather than an empirical study with a defined sample size.	
A.D. Faigenbaum & G.D. Myer (2010)	The study examines current literature and evaluates	The research concludes that resistance training can be

	epidemiological data related to injuries from resistance exercise, weightlifting, and powerlifting among children and adolescents. The document includes a table of resistance training studies in youth, detailing participant numbers. For example, Vrijens (1978) had 28 boys aged 10–16, and Sewall and Micheli (1986) had 18 children aged 10–11.	safe, effective, and beneficial for children and adolescents when properly supervised by qualified professionals. It highlights that the majority of injuries are accidental and often due to poor technique and inappropriate training loads. Regular, well-designed resistance training programs can enhance strength, improve motor skills, and reduce the risk of sports-related injuries.
Young, W., Benton, D., Duthie, G., & Pryor, J. (2001)	The subject of the research in the document you provided is the effects and methodologies of resistance training specifically aimed at improving short sprint performance and maximum-speed sprinting. Regarding the samples used in the study, specific details such as the number of participants or detailed demographics are not provided in the visible text of the document.	The research concludes that short sprints benefit from maximum strength and explosive power training, while maximum-speed sprints require reactive strength training.

DeWeese, B. H., Hornsby, G., Stone, M., & Stone, M. H. (2015)	The research subject of the document is planning and implementing strength-power training programs for track and field athletes. There are examples and samples provided throughout the document to illustrate training programs, variations within microcycles, and balancing workload.	The document discusses research findings on strength-power training programs for track and field athletes, focusing on practical application. It stresses the significance of periodization, training principles like overload and specificity, and phase potentiation. Key points include workload balance, fatigue management, timing peak performance, and utilizing diverse training methods for optimal strength-power gains. The research offers valuable guidance for coaches and athletes in designing effective training programs for track and field events.

7 Evaluation of thesis success

The success of the thesis is contingent upon several key factors established in a systematic and collaborative manner. Firstly, the foundation of success lies in the careful selection and discussion of a valid thesis topic. Through dialogues between the students and the commissioning party, the chosen topic of power development with resistance training was mutually agreed upon, ensuring alignment with the research objectives.

Subsequently, a pivotal step in the evaluation of success involves discussions with teachers to assess the validity of the chosen sports topic and the students' capability to effectively complete the thesis. Drawing upon the students' 2.5 years of dedicated study in physical coaching at Kajaani University of Applied Sciences (KAMK), the relevance of the topic to their capabilities is substantiated.

The research process for the thesis is integral to its success, relying on the gathering of reliable sources from reputable platforms such as Google Scholar or PubMed. This approach ensures the incorporation of scholarly and credible information into the thesis, contributing to the overall robustness of the research.

In summary, the success of the thesis is intricately woven into the meticulous selection of a valid topic, ongoing dialogues with educators, comprehensive research from reliable sources, and a client-focused approach commissioning party’s feedback. The adherence to these outlined steps serves as a robust framework for evaluating the success of the thesis.

8 Results

The strength and power training program for teenage runners in off and on-season is designed to enhance their overall athletic performance by focusing on the key theoretical principles outlined in this thesis. The program is structured to address the specific needs of teenage runners during both off-season and on-season periods, with a focus on developing strength, power, and speed.

To create an effective off-season and on-season training program for teenage runners, several key factors must be considered. The primary goal during the off-season is to build a solid foundation of strength and power that will serve as the base for on-season training. This involves focusing on exercises targeting the lower body, core, and upper body, with two days of strength training per week. During the on-season, the focus shifts to maintaining and refining strength and power while incorporating specific exercises and drills to enhance running performance. The program should be structured with a periodized approach to ensure progressive overload and avoid plateaus.

The annual plan should span 12 months and be divided into various training phases, including preparatory, competitive, and transition phases. Each phase should be further subdivided into microcycles and macrocycles, allowing for adjustments in volume and intensity based on individual needs and progress. The transition phase, also known as the compensation phase, should focus on alleviating physiological and psychological fatigue, promoting athlete recovery, and preparing for the upcoming season. Training volume should be reduced during this phase, with a focus on general training and minimal technical development. Overall, the off-season program should aim to develop a strong foundation of strength and power, while the on-season program should focus on maintaining and refining these physical qualities to support running performance. By combining theoretical principles with a structured and periodized strength and power training program, teenage runners can develop the necessary attributes to excel in sprinting[38b]. Individualized approaches, nutritional strategies, and recovery practices should also be considered for optimizing performance and overall athletic development.

In conclusion, an effective off-season and on-season training program for teenage runners should incorporate a balanced mix of strength and power exercises, structured periodization, and a focus on individual athlete needs to enhance overall athletic performance, speed, and explosive strength.

8.1 Result of research questions

What is the impact on strength and power training plans on the performance of teenage runners during both off and on season?

During off season training, the primary focus is building foundational strength and power. This period is crucial for enhancing the physiological and biomechanical capabilities of teenage runners without the pressure of competition. The key benefits include:

1. Increase muscular strength and power: resistance training during the off season helps improve muscle strength and power, which are critical for sprinting.
2. Improve biomechanics: off season training allows athletes to focus on improving their running mechanics
3. Enhance neuro adaptations: the off season is an optimal time to develop neuro factors that contribute to better motor unit recruitment and faster nerve conduction, improving overall sprint performance.

In contrast, the on-season training focuses on maintaining the gains achieved during the off season while emphasizing speed and specific performance skills. The primary impacts include:

1. Maintenance of strength and power: the on-season training ensures that the strength and power developed during the off season are maintained. This involves lower volume but higher intensity workouts to avoid fatigue while keeping the muscles conditioned.
2. Specificity and technique: during the competition season, training becomes more specific to the demands of sprinting. This includes drills that mimic race conditions and refine technique.
3. Speed and explosiveness: on season training prioritises speed work and explosive drills to ensure that athletes can translate their strength gains into faster sprint times.

What is the difference in the program design used in off and on season?

Off-Season: The program is typically higher in volume with a focus on building strength, power, and foundational skills. It includes more resistance training and general conditioning exercises.

On-Season: The program shifts to lower volume but higher intensity, with more specific sprint training and competition preparation. The focus is on maintaining strength, optimizing speed, and fine-tuning technique.

What are the types of recovery that should be used during the program?

Effective recovery strategies are crucial throughout both seasons:

1. Active Recovery: Incorporating light exercises and mobility work to promote blood flow and reduce muscle stiffness.
2. Rest and Sleep: Ensuring adequate sleep and rest days to allow the body to recover fully from intense training sessions.
3. Nutritional Support: Proper nutrition to support muscle repair and energy levels.
4. Physiotherapy and Massage: Regular physiotherapy sessions and massages to prevent and address any muscular issues.

8.2 Final output

The creation of power and strength training plans for teenage runners during the off and on seasons is a strategic process designed to maximize athletic performance while minimizing injury risks. For the off-season, the plan focuses on building foundational strength and power, utilizing higher volume and moderate to high-intensity workouts. This period emphasizes compound movements, plyometric exercises, flexibility, and core stability to develop overall muscle strength and improve biomechanical efficiency. The off-season plan includes frequent and varied sessions to enhance general athleticism and prepare the body for the demands of the competitive season. In contrast, the on-season plan shifts to maintaining the gains achieved in the off-season with lower volume but higher intensity workouts. This phase prioritizes sport-specific drills, high-intensity interval training, and continued plyometric exercises, with a strong emphasis on optimizing sprinting mechanics and performance. The frequency of training sessions is reduced to avoid overtraining, and recovery strategies become paramount to ensure athletes remain in peak condition. By tailoring the program design to the distinct needs of each season, teenage runners can achieve sustained improvements in performance, maintain their physical condition, and reduce the risk of injuries. This approach ensures a balanced development of strength and power, crucial for enhancing sprint performance throughout the year.

9 Discussion

In Kajaani, athletics is on the rise among young people, and there has been success. In recent years, the athletes of our youth coaching group have won several SM medals and numerous other good positions. With our team, we have also participated in SM messages. Kajaani's Kipinä youth competition coaching group has around fifteen multi-talented athletes training. Athletes usually move from sports schools to a competitive coaching group at around 13-14 years of age, with the aim of first getting into the championships of their age group and later succeeding there. As a rule, the exercises are organized as joint exercises, where the themes are speed, speed endurance, muscle condition, strength and sports training. In coaching, we try to take into account each person's personal wishes, and we are able to offer coaching in almost all athletics (Kajaani Kipina, 2022.)

9.1 Conclusion

This thesis has presented a comprehensive framework for designing and implementing a strength and power training program for teenage runners during both the off-season and on-season. By focusing on the key theoretical principles of strength and power development, as well as the specific needs and demands of teenage runners, the proposed program aims to enhance overall athletic performance and running efficiency. The off-season program emphasizes the development of a strong foundation of strength and power, while the on-season program focuses on maintaining and refining these physical qualities to support running performance. The periodized approach, with progressive overload and a balance of strength, power, and running-specific exercises, ensures that the program is tailored to the unique needs of teenage runners.

By building upon the foundation laid in this thesis, future researchers can contribute to the growing body of knowledge on strength and power training for teenage runners, ultimately enhancing the overall performance and well-being of this athlete population.

9.2 Reliability and Validity

Reliability

Consistency: Sources were gathered from reputable academic databases such as Google Scholar, KAMK Finna, ResearchGate, PubMed, and EBSCO, focusing on sport-related materials. Irrelevant titles were excluded to align with the research questions.

Documentation: The research followed a structured framework with a systematic approach.

Peer Review: The work underwent peer review by colleagues to ensure accuracy and reliability.

Validity

Credibility of Sources: The selected literature met criteria including authorship, publication source, date of publication, purpose and audience, and evidence and references.

Methodological Rigor: The literature review was conducted using a light systematic approach, starting with a clear research question on the impact of strength and power training on teenage runners. Comprehensive searches were conducted across databases like Google Scholar, PubMed, and ResearchGate, using specific keywords and examining bibliographies and conference proceedings. Inclusion criteria were set for sources from 1980-2024, in English, freely accessible, and academic. Exclusion criteria eliminated older, non-English, paid, non-academic, and irrelevant studies. Data extraction and quality assessment were performed using standardized checklists, followed by narrative synthesis to summarize findings and develop a theoretical framework. This rigorous process, validated through feedback and reliance on credible sources, ensured the review's validity and robustness.

Justification of Interpretations: The interpretation provides evidence of the positive impact of strength and power training on sprint performance. It offers an overview of annual periodization, ensuring a comprehensive understanding of training cycles. Additionally, it addresses the safety of resistance training for young athletes, the importance of recovery periods, and presents examples of hypertrophy, strength, and power exercises. All these elements are highly relevant and beneficial to the field of sprinting.

9.3 The use of artificial intelligence/supportive intelligence

According to KAMK's guidelines for the use of artificial intelligence/supportive intelligence, the tool can be used with teaching and to support writing. Therefore, in this work AI has been used to correct spelling and grammar mistakes only! AI is not used as a source, all sources are collected from the academic databases.

9.4 Development of professionalism

By doing our thesis we improved on multiple professional aspects. We gained in-depth knowledge of the specific needs and training considerations for teenage athletes. By researching the topic extensively, we developed expertise in areas like proper exercise selection, periodization, and managing training load for this population. Learned how to design a comprehensive, evidence-based training program. Putting together a program that addresses all the key areas like movement quality, general strength, power development, and sport-specific training showed our ability to take a holistic approach.

We also developed skills in program implementation and coaching. Even if we didn't get to work directly with athletes, Even if we didn't get to work directly with athletes we managed to progress the program and demonstrated our coaching abilities.

Moreover, we practiced critical thinking and problem-solving. Navigating the challenges of creating an effective program, like managing fatigue, individualizing the plan, and troubleshooting issues, built our capacity to think through complex problems. Gained experience in the research process. Conducting a literature review, synthesizing information, and drawing conclusions from multiple sources is a valuable skill that will served us well as professionals.

Overall, taking on a thesis project like this allowed us to apply our knowledge, develop practical skills, and demonstrate our ability to think critically - all of which are essential for success as a strength and conditioning professional working with youth athletes. The depth of knowledge we gained on this specific topic also sets us up to be an expert in this area moving forward.

9.5 Opportunities for Future Research:

This thesis provides a solid foundation for strength and power training in teenage runners, but there are several avenues for future research and exploration:

1) Longitudinal Studies: Conducting long-term studies to assess the cumulative effects of the proposed program on running performance, injury rates, and overall athletic development over multiple seasons.

2) Individualized Approaches: Investigating the efficacy of tailoring the program to individual athlete needs, such as considering factors like maturation status, training history, and specific weaknesses or imbalances.

3) Nutritional and Recovery Strategies: Exploring the impact of integrating optimal nutritional and recovery practices (e.g., hydration, sleep, and regeneration) to support the strength and power training program.

4) Comparison with Other Training Modalities: Comparing the effectiveness of the proposed program with alternative training approaches, such as plyometric-focused or endurance-based programs, to identify the most optimal methods for teenage runners.

5) Gender-Specific Considerations: Examining potential differences in the application and effectiveness of the program for male and female teenage runners, accounting for physiological and developmental variations.

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Appendix 1:

Design

Resistance training is a crucial component in improving athletic performance, particularly in enhancing strength, power, and speed. Research indicates that resistance training can lead to increased muscular strength, power, speed, hypertrophy, local muscular endurance, balance, and coordination. Additionally, resistance training can improve force-time characteristics, allowing athletes to generate force more effectively in activities like jumping and sprinting.

Specifically for sprinters, integrating resistance training into their routine can be beneficial for enhancing sprint performance, especially in short and maximum-speed sprints. Exercises focused on specific muscle groups, such as plyometrics, can help develop reactive strength crucial for maxi-mum-speed sprinting. Furthermore, resistance training can enhance stride length by increasing muscle strength and power, ultimately improving running speed. This improvement in strength can lead to longer and more powerful strides, contributing to optimal running performance.

Overall, resistance training plays a significant role in the development of strength, power, and speed for athletes, including sprinters. By following age-appropriate training programs and focusing on proper technique, athletes can enhance their physical fitness and performance through resistance training.

Young teenagers can safely engage in resistance training under proper supervision and with age-appropriate training programs. According to research, children and adolescents can start weight-lifting when they are prepubertal or post-pubertal adolescents. It is recommended that they begin with low-resistance exercises until they perfect proper technique, gradually increasing weight as they can perform 8 to 15 repetitions with good form. Studies have shown that teenagers can experience a substantial improvement in strength within a relatively short period, with older teenagers showing greater gains in strength due to hormonal changes and increased muscle mass. Proper supervision, technique, and safety precautions are crucial to reduce the risk of injury when engaging in resistance training, with an instructor-to-student ratio of no more than. Overall, with the right guidance and training programs designed by qualified professionals, resistance training can be a valuable tool for enhancing strength and reducing the risk of sports-related injuries among young athletes.

Offseason starts with preparatory phase I:

Preparatory phase I (3 months)

General

- Core strength (overall conditioning)
- Focus on mainly hypertrophy and maximal strength.
- More vertical movement
- High volume

Specific training

> Volume stays the same while intensity increase

> Biomechanically sprint alike movements in strength training

> Increasing use of horizontally directed movements

An example of a seven-day microcycle of high training load during the preparatory phase I. (Enroth, 2020)

DAY	MORNING	AFTERNOON
1	Rest	Rest
2	Running technique	Maximum strength
3	Circuit training + tempo	Hill + plyometric
4	Rest	Body care + mobility
5	Speed	Hypertrophy

6	Rest	Mobility
7	Aerobic endurance	Rest

Examples of a hypertrophy/strength session:

Exercises	Repetitions
Back squat	Hypertrophy: 6-12 reps (3-4 sets) Strength: 1-6 (3-4 sets)
Cable hip flexion	Hypertrophy: 6-12 reps (3-4 sets) Strength: 1-6 (3-4 sets)
Nordic hamstrings	Hypertrophy: 6-12 reps (3-4 sets) Strength: 1-6 (3-4 sets)
Smith machine calf raises	Hypertrophy: 6-12 reps (3-4 sets) Strength: 1-6 (3-4 sets)
Bench press	Hypertrophy: 6-12 reps (3-4 sets) Strength: 1-6 (3-4 sets)
One arm dumbbell rows	Hypertrophy: 6-12 reps (3-4 sets) Strength: 1-6 reps (3-4 sets)

Example of variations of exercises for strength and hypertrophy training program:

Variation 1	Variation 2	Variation 3
Deadlift	Front squat	Single leg squat
Step ups	Romanian deadlift	Nordic hamstring curls
Barbell lunge	Barbell reverse lunge	Barbell walking lunge
Smith machine calf raise	Dumbbell single leg calf raise	Dumbbell walking calf raise
Dumbbell press	Shoulder press	Bench press
Single arm rows	Smith machine rows	Machine rows

A loading paradigm of 2:1 and 3:1 is commonly used, a relatively high training load across 2 or 3 microcycles followed by a microcycle of unloading for recovery purposes and to avoid any injuries.

Recommendations for maximal strength, power, and endurance strength training. (Enroth, 2020)

Method	**Load(%1RM)**	**Repetition/set**	**Preferred implementation**
Maximal strength			
Neural	90-100	1-3	Weight room
Hypertrophic & neural	70-90	3-6	Weight room
Hypertrophic	60-80	6-12	Weight room
Power			
Neural	30-60	1-10	Weight room, plyometric with added weight

Hypertrophic & Neural	30-80	1-10	Weight room, plyometric with added weight
Endurance strength			
Anaerobic	20-60	10-30	Weight room, circuit training
Aerobic	0-30	>30	Circuit training

Tapering:

Tapering in sprint training is a strategic approach where the training load is progressively reduced before a competition to optimize performance. It involves a gradual decrease in training volume, typically by 40% to 50% over 8 to 14 days, spread across two microcycles. The goal is to alleviate accumulated physiological and psychological fatigue while maintaining or slightly increasing training intensity to prevent detraining. Tapering includes adjustments in strength training, focusing on reducing volume and frequency while preserving strength levels. By allowing for recovery and regeneration, tapering helps prevent overtraining and enhances performance capacity, ensuring sprinters peak at key competitions. Recovery methods like adequate sleep and personalized plans for competitions in different time zones are crucial during tapering. Overall, tapering is a critical aspect of sprint training and coaching, aiming to optimize athletes' preparedness and performance.

Appendix 2

Competitive phase I (2.5 months)

Pre-competition:

- During specific preparatory

Phase (reduce volume to 25%-50%)

- Peak of intensity is 2-3 weeks.

before competition

- Explosive strength exercises

are emphasized

Official competition phase:

> No high intensity strength training

during

An example of a seven-day microcycle of high training load during the competitive phase I. (Enroth, 2020)

DAY	MORNING	AFTERNOON
1	Rest	Rest
2	Body care	Block start + acceleration
3	Speed endurance	Rest
4	Power (short)	Rest
5	Light preparative exercise	Rest

6	Competitive	Competition
7	Competitive	Competition

Example of exercises for power training.

Exercises	Repetitions
Power/hang clean	2-6 reps (3-4 sets)
Weighted jump squat	2-6 reps (3-4 sets)
Snatch pull	2-6 reps (3-4 sets)
Anchor hops	2-6 reps (3-4 sets)

Example of variations of exercises for strength and hypertrophy training program

Variation 1	Variation 2
Power clean	Quarter squat
Split jerk	Clean and jerk
Snatch pull	Split jump
Ankle hops	Depth jump

Appendix 3

Transition I (1 microcycle)

The commencement of the first transition phase immediately ensues upon the conclusion of the indoor competition phase. Sprinters, having undergone protracted periods of arduous training and intense competitive engagements, are subject to substantial cumulative fatigue and physiological stress. Prolonged exposure to such stressors may precipitate overtraining, thereby diminishing performance capacity. Thus, the transition phase is instrumental in facilitating recovery and regeneration subsequent to the competitive phase. Characterized by a week-long period of reduced intensity, this phase allows sprinters to prepare for the ensuing training phase. It is noteworthy that certain practitioners may choose to forgo the inclusion of a transition phase subsequent to the initial competitive phase.

Appendix 4

Preparatory phase II (2 months)

An example of a seven-day microcycle of high training load during the preparatory phase II. (Miro Enroth, 2020)

DAY	MORNING	AFTERNOON
1	Rest	Rest
2	Mobility + core strength	Acceleration + circuit training
3	Tempo	Maximal strength
4	Rest	Body care
5	Submaximal speed	Maximal strength
6	Rest	Tempo
7	Rest	Rest

While preparatory phase I focuses more on building a physiological base and gradually increasing training intensity, preparatory phase II concentrates on higher volumes and intensities with less gradual familiarization. The strength and power training progressions in both phases aim to enhance the athlete's ability to generate power and speed for sprinting performance.

Appendix 5

Competition phase II (3.5 months)

An example of a seven-day microcycle of high training load during the outdoor season. (Enroth, 2020)

DAY	MORNING	AFTERNOON
1	Rest	Rest
2	Block start + acceleration	Power
3	Rest	Light exercise + body care/massage
4	Power (short)	Rest
5	Rest	Rest
6	Competition	Competition
7	Competition	Competition

- Focuses on developing maximal velocity and sprint-specific endurance.
- Training volume is significantly reduced during this phase, with an emphasis on increasing training intensity and peaking at optimal times to maximize performance during sprint races.

Appendix 6

Transition phase II (one month)

Transition phase II, also known as the compensation phase, focuses on removing physiological and psychological fatigue, allowing the athlete to fully recover, inducing regeneration, and preparing for a new annual season. This phase is crucial for injured athletes as it is used for rehabilitation and restoration of movement capacity. It involves unloading and active rest, along with exercises targeted to improve weaknesses, musculature stabilization, and general physical preparation. The training components during this phase are focused on general training with minimal technical development, maintaining approximately 40-50% of the competitive phase load. It is important to avoid total unloading (training pause) during this phase to prevent excessive decrease in performance. Transition phase II typically lasts up to one month before the next annual training plan is initiated.

Appendix 7

Recovery.

During the recovery period, sprinters focus on several key aspects to allow their bodies to rest, regenerate, and prepare for future training and competition. Recovery strategies include various interventions and modalities such as passive rest, active recovery, massage therapy, and proper nutrition. Passive recovery techniques involve activities like sleeping and ensuring adequate nighttime rest, with elite athletes typically requiring 8 to 10 hours of sleep per night. Disturbances in sleeping rhythms, especially during competitive seasons involving travel across multiple time zones, can impact performance and require individualized recovery plans. Active recovery involves light exercise, stretching, and other muscle care exercises, which can aid in lactate clearance, temperature regulation, central nervous system activity, and reduction of muscle soreness.

Furthermore, recovery strategies may also incorporate nonsteroidal anti-inflammatory drugs and thermotherapy (e.g., sauna, hot water immersion) or cryotherapy (e.g., cold-water immersion) to promote recovery and reduce inflammation and soreness. The transition phase II, also known as the compensation phase, plays a crucial role in an annual training plan by allowing athletes to fully recover, regenerate, and eliminate physiological and psychological fatigue. This phase is essential for preparing athletes for the next annual season and may involve unloading, active rest, rehabilitation for injuries, and addressing weaknesses or imbalances through specific exercises. By implementing a well-rounded recovery plan that includes rest, nutrition, active recovery, specialized modalities, and individualized strategies, sprinters can optimize their recovery and enhance their overall performance.

This product offers an overview of annual periodization, ensuring a comprehensive understanding of training cycles. Additionally, it addresses the safety of resistance training for young athletes, the im-portance of recovery periods, and presents examples of hypertrophy, strength, and power exercises. All these elements are highly relevant and beneficial to the field of sprinting.