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Original Article

Neuro-muscular training for injury prevention of students-rock climbers studying in the specialty "Physical Education and Sports": a randomized study

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Abstract
Aim: to reveal the influence of neuromuscular training in combination with an educational program on the injury risk to students – rock climbers – future specialists in the field of physical education and sports. **Material and methods.** Design. This study was randomized with parallel randomization. The control (n = 22) and the experimental (n = 20) groups were made up of rock-climbers studying in the specialty "Physical education and sports" in 4 universities of Ukraine. The experimental group used neuromuscular training developed for climbers. Neuromuscular training involved: 1 - the use of exercises specific to rock climbing; 2 - concentration on the correct execution of the basic elements of the technique; 3 - application by exercises in a closed kinematic chain; 4 - application of the educational program. Recorded finger injuries during 1 year with using the experimental program. The indicators of the Hazard Ratio (HR) and the Odds Ratio of getting finger injuries were calculated. **Results**. It has been revealed that the neuromuscular training has been stashed in the second half of the year with the use of finger injuries. Low-collapse finger injury in the control group by 2.27 times in the experimental group ((HR) = 2.27, 95% confidence interval (95% CI) = 1.9-2.56; p<0,05). Injury to normalize finger injury in average folding in the control group 3.64 times in the experimental group ((HR) = 3.64, 95% confidence interval (95% CI) = 2.8-3.92; p<0,05). Exceptional risky eliminate finger injury in high folding in the control group by 2.73 times in the experimental group ((HR) = 2.73, 95% confidence interval (95% CI) = 2.34-3.46; p<0,05). **Conclusions**. The developed program of neuromuscular training in combination with exercises in a closed kinematic chain and with an educational program can be recommended for the injury prevention students - rock climbers studying in "Physical Education and Sports".
Key words: students, rock climbing, injuries, neuromuscular training, educational program

Introduction

Currently, the importance of injury prevention technologies in the training of specialists in various fields is increasing. The field of physical education and sports is no exception, since it has its own specifics. A future specialist in physical education and sports should improve qualifications in the chosen sport and learn the basics of other sports. This creates the conditions for an increase in injuries. Therefore, an important direction of research at the present time is the development of teaching technologies that will prevent injuries of students - future specialists in physical education and physical education.

Currently, according to databases Endnote, Web of Science, Scopus, PubMed, many studies are devoted to sports injuries of students. This indicates the high urgency of this problem in the world. Scientific works on this topic can be divided into 2 groups: 1 - articles devoted to sports injuries of students in general (the largest number of articles); 2 - articles devoted to sports injuries of students enrolled in the programs "Physical Education and Sports". This program involves training physical education teachers or coaches in a particular sport.

Many authors (Lynall et al. 2018; Martinez-de-Quel-Perez, et al., 2019; McLoughlin et al., 2019; Russel et al., 2019; Sang, 2019; Slater et al., 2019; Sommerfield et al., 2020) note a high prevalence of injuries among students involved in various sports. In most studies (Asperti et al., 2017; Clifton et al., 2018; Fraser et al., 2017; Kerr et al., 2017), traumatic exposure was defined as the participation of one student-athlete-amateur in one

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workout or game, and expressed as an impact on the athlete (AE). This value ranges from 1.82 to 15.29 per 1000 student athletes who participated in training or games (A-E). The most traumatic sports are team ball sports and wrestling.

Among the scientific works devoted to the traumatism of students, a special place is occupied by the work devoted to the prevention of traumatism of students enrolled in the programs "Physical education and sports" In a study by Goossens et al. (2019) showed that sports injuries sustained by students enrolled in Physical Education and Sports programs can seriously damage the subsequent career of a physical education teacher and coach. Goossens, L., et al. (2019) also indicate that Physical Education and Sports students spend approximately 15–19 hours per week on sports theory and practice. The content of the programs of students enrolled in the programs "Physical Education and Sports" in different countries may be different. It should be noted that in Ukraine, the amount of time allocated for the practice of sports activities is about 20-26 hours per week. In Ukraine, in different universities, depending on the sports qualifications of students and the characteristics of the training program, from 6 to 18 hours a week are spent on practicing the chosen sport and from 6 to 20 hours a week are spent on other sports. Hence, a high risk of injury can be expected.

Goossens, L., et al. (2019) indicate that relatively few studies have focused on injury risk in physical education and sports students. However, the data available in the literature confirm that future specialists in the field of physical education and sports have an increased risk of injury. Lysens et al. (1989) found 1.7 injuries for every physical education and sport student during their first year in Belgium. In Austria, Ehrendorfer (1998) reported more than three injuries per Physical Education and Sports student over an average of 2.35 years. Likewise, Flicinski (2008) reported musculoskeletal pain during the previous year in almost half of the group of Polish students enrolled in the Physical Education and Sports program. Goossens, L., et al. (2019) found that the most effective injury prevention programs are comprehensive programs that include neuromuscular training. These authors, based on the analyzed literature, identified the following aspects of injury prevention programs that can be used for students enrolled in the courses "Physical Education and Sports": 1 - Functional strength training; 2 - Stretching; Warm up (WU) or cool down (CD); 3 - Dynamic stability training for the lower limbs; 4 - Core stability. Also, these authors note the need to combine comprehensive programs with various educational programs for informing about the causes of injuries and means of preventing injuries. Neuromuscular training is a central component in the most effective comprehensive injury prevention programs. Neuromuscular connection is the conscious ability to feel your muscles and regulate their level of engagement during exercise (Emery, 2020). It is the developed neuromuscular connection that distinguishes a beginner from a professional athlete. The connection of muscles with the brain involves: the ability to consciously strain the muscles, more technical performance of exercises. One of the elements of neuromuscular training is concentration on the technique of the exercise. Closed chain exercise is another important component of comprehensive injury prevention programs. Thus, Coppack et.al. (2011) demonstrated the effectiveness of an injury prevention program for girls serving in the army, one of the components of which was exercises in a closed kinematic chain for the quadriceps muscle. The exercises were also aimed at strengthening the gluteal muscles. A 75% reduction in the risk of injury was found (unadjusted hazard ratio = 0.25; 95% CI, 0.13-0.52), and it was concluded that an injury prevention program that includes exercises in a closed chain for the quadriceps muscles combined with strengthening the gluteus muscles. Augustsson et.al. (1998) showed a higher efficiency of exercises in a closed kinematic chain compared to exercises in an open kinematic chain for gaining muscle mass and increasing the jump up.

Thus, the analyzed literature indicates the high efficiency of the use of comprehensive injury prevention programs. These programs include exercises aimed at strengthening various muscle groups. Exercises can be performed during warm-up, cool-down, at home. The effectiveness of these exercises is increased by using an educational program that informs students about the causes of injuries and about preventive measures. Neuromuscular training is a central component in all comprehensive programs. Some programs show the effectiveness of using exercises in a closed kinematic chain.

Students' injury prevention programs were analyzed mainly for team playing sports and wrestling. It should be noted that from the point of view of students 'injuries (including students - future teachers of physical education and sports), such sports as rock climbing were not analyzed, despite the presence of publications on the nature of climbers' injuries. However, at present this kind of sport is becoming more and more popular among young people, including among students in general, as well as among students - future teachers of physical education and sports. Rock climbing has now become an Olympic sport (Kozina et.al., 2016, 2020a, 2020b). This will significantly increase the level of sports professionalism and affect the volume, intensity of loads, modes of the training process and the nature of injuries (Lutter et.al., 2017). According to studies (Hochholzer et.al., 2015; Schoffl et.al., 2015), there is a trend towards a significant increase in upper limb belt injuries. The most commonly injured areas are the fingers, shoulder and forearm (Jones et.al., 2016; Woollings et.al., 2015). Therefore, a promising direction, in our opinion, will be the development of programs to prevent injuries of students - future teachers of physical education and sports while practicing rock climbing.

Based on the analyzed literature, a hypothesis was put forward: for the prevention of traumatism among students-rock-climbers studying in the specialty "Physical Education and Sports" there will be an effective program consisting of the following components: 1 - neuromuscular training, one of the aspects of which is the

use of exercises in a closed kinematic chain; 2 - educational program informing students about the causes and means of injury prevention.

Aim: to reveal the influence of neuromuscular training in combination with an educational program on the injury risk to students – rock climbers – future specialists in the field of physical education and sports.

Material and methods

Participants

This study was controlled randomized with parallel randomization. The randomization was carried out by an independent expert in a random way, who was not aware of the purpose of the work and was not interested in the final result of the study.

Both control (n = 22) and experimental (n = 20) groups consisted of students - climbers studying in the specialty "Physical Education and Sports" in 4 universities of Ukraine, aged 18-19 years, male. The body length of athletes in the control group was 172.5 ± 8.5 cm, body weight - 65.2 ± 6.5 kg; body length of athletes in the experimental group was 173.4 ± 8.7 cm, body weight - 66.1 ± 6.6 kg ($p > 0.05$). The number of finger injuries registered during 6 months before the experiment was in the control group: 2 injuries of low severity (1.01 A-E), 1 injury of medium severity (0.51 A-E), 0 injuries of severe severity; in the experimental group - 2 injuries of low complexity (1.11 A-E), 1 injury of medium severity (0.55 A-E), 0 injuries of severe complexity ($p > 0.05$).

Procedure

Initially, upper extremity finger injuries were recorded in both groups for 6 months to determine the initial level of injury. Traumatic impact was defined as the participation of one student - climber in one training session or competition and was expressed as the impact on the athlete per 1000 training sessions (competitions) (A-E).The groups trained according to the generally accepted plan 3-4 times a week, the number of training hours was the same in both groups during the year. As a neuro-muscle training were used to prevent injuries of the upper extremities. Neuromuscular training involved the use of exercises specific to climbing. Neuromuscular training also involved concentration on the correct performance of the basic elements of technique in combination with exercises in a closed kinematic circuit and with an educational program. These tools were used in the experimental group. The control group did not use special exercises to prevent injuries.

Injury registration method

Cases of injuries and diseases of the upper extremities were first recorded for 6 months to determine the initial level of injury in both groups, and then - for a year in both groups. The following injuries were registered: injuries and diseases of the fingers in severity: minor, moderate, severe. Minor injuries include those that heal in less than 1 month, moderate injuries that heal in 2-3 months, and complex injuries include those that heal within 6-12 months, and their effects can last a lifetime.

Intervention program

Based on the biomechanical analysis of hanging techniques in climbing (Kozin, 2019;Kozin et.al., 2020, Kozin et.al., 2021), means were selected and systematized to prevent injuries of the upper extremities. The means were physical exercises that are performed independently, as well as with a trainer or physical therapist.

According to modern authors, one of the most common causes of injuries and diseases of the upper extremities is muscle imbalance due to the predominance of flexion movements over extension in the elbow joint in the training process of climbers. In this regard, we have included in the training process exercises aimed at strengthening the extensor muscles, such as various push-ups. In addition, as shown by our previous studies (Kozin, 2019, Kozin et.al., 2020, Kozin et.al., 2021), the correct technique of hanging on the one arm in climbing involves the inclusion of muscles not only of the upper extremities, but also the muscles of the torso and legs (Fig. 1, B). In case of incorrect hanging technique, mainly the muscles of the upper extremity are involved (Fig. 1, A). Therefore, with the right technique ofhanging on the one arm in climbing, the inclusion of the muscles of the torso and legs creates additional links in the kinematic chain (Kozin, 2019, Kozin et.al., 2020). As a result, the upper limb has less load than with the wrong technique of hanging on the one arm in climbing. This ensures the achievement of sports results and prevents injuries. That is why neuromuscular training involved conscious concentration on the correct technique of performing hanging on the one arm in climbing.

Fig. 1. Incorrect (A) and correct (B) technique of hanging on one arm in climbing (source: photo by the author; Kozin, 2019, Kozin et.al., 2020, Kozin et.al., 2021)

Based on our findings and based on the results of research Augustsson et.al. (1998), Coppack et al. (2011), Kozin et.al. (2021), we have included in the injury prevention program exercises performed in a closed kinematic chain. This is due to the fact that the closed kinematic chain involves all the muscles that form this kinematic chain (Fig. 2). The neuromuscular training program involved a conscious concentration on the inclusion of all the muscles of the closed kinematic chain in the process of performing each movement.

Fig. 2. Example of an exercise in a closed kinematic circuit (squeezing on rings) (source: photo by the author - Serhii Kozin) (Kozin et.al., 2021)

Also included in the training process exercises for pronation-supination with the exception of the concentric phase, which are performed in an eccentric mode (Fig. 3). The neuromuscular training program involved conscious concentration on slow pronation-supination and on the smoothest involvement of muscles in the eccentric mode. In addition, stretching of flexors, extensors of the hand and fingers, as well as massage were used.

Fig. 3. Exercises with a dumbbell in the eccentric mode (source: photo by the author - Serhii Kozin)Kozin et.al., 2021)

The educational program of injury prevention included: 1. Knowledge of dynamic anatomy, 2. Knowledge of the laws of movement control, 3. Understanding the causes and means of injury prevention. Theoretical classes revealed the basic and clinically significant concepts of biomechanics, functional anatomy in motion models. The degrees of freedom of movement of the upper and lower extremities, torso, neck, pelvis were also considered, the structure of joints and features of movements in them were analyzed. Each muscle that provides movement to the upper extremities is then examined in terms of anatomy and the function it performs. At the end of the characteristics of each muscle, the main pathologies provided by this muscle are considered. At the next stage, we studied the manual and functional methods of physical therapy to prevent injuries and diseases, as well as - to restore function.

Statistical analysis

To determine the impact of the developed technology on the risk of injury, the following indicators were determined: risk (incidence) of injury, chance of injury, Hazard Ratio and odds ratio using the computer program SPSS-17 SPSS 17.0 for Windows software (SPSS Inc., Chicago, Illinois, USA), Crosstabs option.

To determine the impact of the developed technology on the risk of injury, the following indicators were determined: risk (incidence) of injury, chance of injury, Hazard Ratio and Odds Ratio. Traumatic impact was defined as the participation of one student - climber in one training session or competition and was expressed as the impact on the athlete per 1000 training sessions (competitions) (A-E). The A-E value was defined as the ratio of the total number of trainings (competitions) (during which injuries were recorded, in our case it was 180) multiplied by the number of students - climbers (in our case it was 20 for the experimental group and 22 for the control group) , to the recorded number of injuries multiplied by 1000 training sessions (competitions).

The risk (incidence) of injuries was definedbystandardmethods (Knowles, S., Marshall, S.W., Guskiewicz, K.M., 2006): as the ratio of the number of injuries to the total number of athletes in the analyzed

group. The Hazard Ratio was determined by the Hazard in the control group to the Hazard in the experimental group. The chance of injury was defined as the ratio of the number of injuries to the number of uninjured athletes in the analyzed group (Knowles, S., Marshall, S.W., Guskiewicz, K.M., 2006). The odds ratio was defined as the Odd of injury in the control group to the Odd of injury in the experimental group. These indicators were determined separately for all analyzed types of finger injuries (low, medium and severe) (Knowles, S., Marshall, S.W., Guskiewicz, K.M., 2006). To determine the significance of differences between the control and experimental groups at the beginning of the experiment on the indicators of length, body weight, age and number of injuries, the Student's method was used.

The significance of differences in the number and risk of injuries between the control and experimental groups was determined by Student's t-test.

Results

Recording the number of finger injuries received by students - climbers showed that during the year the following number of finger injuries was observed: in the control group: the number of injuries of low complexity = 5 (1.26 A-E); the number of moderate injuries = 4 (1.01 A-E), the number of high injuries = 3 (0.76 A-E); in the experimental group: the number of injuries of high complexity = 2 (0.55 A-E), the number of injuries of medium severity = 1 (0.28 A-E), the number of injuries of high complexity = 1 (0.28 A-E) (Table 1).

The incidence (risk) of finger injuries of light, medium and high complexity are presented in table 1 (Table 1).

Table 1

Risk indicators of finger injuries in the control (n = 22) and experimental (n = 20) groups during the year

Group	Low complexity				Medium complexity				High complexity			
	The Injury quantity	The Injury quantity per 1000 A-E	The Hazard	The Odd	The Injury quantity	The Injury quantity per 1000 A-E	The Hazard	The Odd	The Injury quantity	The Injury quantity per 1000 A-E	The Hazard	The Odd
C	5	1.26	0.23	0.29	4	1.01	0.18	0.22	3	0.76	0.14	0.16
E	2	0.55	0.10	0.11	1	0.28	0.05	0.05	1	0.28	0.05	0.05
HR	2.27; 95% CI = 1.9-2.56; p<0.05				3.64; 95% CI = 2.8-3.92; p<0.05				2.73; 95% CI = 2.34-3.46; p<0.05			
OR	2.65; p<0.05				4.22; p<0.05				3.00; p<0.05			

Notes: C – control group; E - experimental group; HR - the Hazard Ratio of getting a finger injury; OR - the Odds Ratio of getting a finger injury; A-E – quantity students*quantity training session (competition)

Discussion

The hypothesis put forward in this study was fully confirmed. It was shown that for the prevention of traumatism among rock-climbers studying in the specialty "Physical Education and Sports", a program of neuromuscular training in combination with an educational program informing students about the causes and means of preventing injuries.

The results obtained confirm the results of a number of authors, who also revealed a positive effect of neuromuscular training on the prevention of sports injuries. Parkkari et al. (2011) proposed a neuromuscular training program with injury prevention counseling to reduce the risk of acute musculoskeletal injury. The authors (Parkkari et al., 2011) conducted a randomized controlled trial that included 968 recruits, including 501 recruits in the experimental group and 467 recruits in the control group. The neuromuscular training program has been used to improve motor skills and body control, and the injury prevention education program has been used to raise awareness of acute musculoskeletal injuries. For neuromuscular training, the authors proposed 9 special exercises. Each of the nine exercises focused on maintaining correct posture, maintaining the stability of the core or posture, hips, knees and ankles (Parkkari et al., 2011).

As a result of applying this program for 6 months, the risk of acute ankle injury in the experimental groups significantly decreased compared to the control groups (adjusted hazard ratio (HR) = 0.34, 95%, confidence interval (95% CI) = 0.15 –0.78). In addition, the intervention groups tended to have less time lost to injury (adjusted HR = 0.55, 95% CI 0.29 to 1.04). Based on the findings, Parkkari et al. (2011) conclude that the proposed neuromuscular training program, combined with injury prevention counseling, was effective in preventing acute ankle and upper limb injuries in young male recruits. These authors believe that such a program can be useful to all young people who regularly play sports.

The results of the studies by LaBella et al. (2011), who suggested that coaches of teams in women's football and basketball should use a special warm-up in combination with the use of information about the causes of injuries. The warm-up combined progressive exercises to strengthen the muscles of the lower extremities, plyometric exercises, balance exercises and agility exercises (LaBella et al., 2011). Athletes were

advised to avoid dynamic knee valgus and land after jumping on bent hips and knees. As a result of the study, LaBella et al. (2011) found that a coach-led neuromuscular warm-up reduces the likelihood of non-contact injuries of the lower extremities in female football and basketball players. Thus, this study demonstrates the effectiveness of a comprehensive injury prevention program in combination with a theoretical component.

The effectiveness of neuromuscular training shown in our study also confirms the data of Emery et al. (2005). These authors propose to apply at home a program of gradual increase in proprioception using a wobbler board in combination with isometric contraction of the abdominal and gluteal muscles. The effectiveness of these exercises, according to the value of the odds ratio, is 0.15 (0.03–0.75).

Pasanen et al. (2008) also conclude that a neuromuscular training program is effective in preventing acute non-contact foot injuries in female football players, and neuromuscular training can be recommended in weekly training for athletes (Dai et.al., 2012; Emery, 2020; Faude et.al., 2017; Gatt, 2014).

The neuromuscular training effectiveness has been shown in recent studies (Javier Robles-Palazon et.al., 2017; McCann et. al., 2011; Owoeye, et.al., 2018, 2020; Rahlfet.ol., 2020; Silvers-Granelli, et.al., 2018; Steffen, K., et.al., 2013; Sugimoto, D ., et.al., 2015).

In addition, the position on the effectiveness of the use of exercises in a closed kinematic chain for the prevention of injuries was also confirmed. This position was based on literature data and on the results of our previous studies. Zakritiykinematichny lancet transferring the inclusion of all the languages that form the kinematic lanceyug. Coppack et al. (2011) recommend, for injury prevention, to perform exercises in a closed kinetic chain for the quadriceps muscle and gluteal eccentric, as well as static stretching of the quadriceps muscle, hamstring, gastrocnemius muscle and iliotibial ligament. The odds ratio of injury without application and with the use of this program is 0.26 (0.13–0.53).

A special educational program that was used in our study increased the impact of neuromuscle training due to increased awareness of exercise. Neuromuscular training involves mental concentration on the correct technique for performing exercises, neuromuscular control when performing certain exercises, and awareness of the muscles involved in movements.

However, in the analyzed literature(Kozin et.al., 2021, LaBella et al., 2011, Parkkari et al., 2011), all proposed neuromuscular training programs included general exercises to strengthen the core muscles, develop balance, and strengthen the leg muscles. In our study, we used injury prevention exercises specific to rock climbing. It should be noted that revealing the effectiveness of the climbing exercises we have developed is relatively new knowledge. with a concentration on the correct implementation of the basic elements of the technique in combination with exercises in a closed kinematic chain and with an educational program.

Conclusions

The use of neuromuscular training in combination with an educational program has been found to reduce the risk of finger injuries. The Hazard Ratio of injury of fingers of low complexity in the control group is 2.27 times higher than the experimental. The Hazard Ratio of finger injury of medium complexity in the control group is 3.64 times higher than the experimental. The Hazard Ratio of finger injury of high complexity in the control group is 2.73 times higher than in the experimental.

The developed neuromuscular training program can be recommended for the prevention of injuries of students - climbers who study in the specialty "Physical Education and Sports".

References

Asperti, A. M., Fernandes, T. L., Marinho, I. M., Pedrinelli, A., & Hernandez, A. J. (2017). Sports injuries among amateur athletes at a brazilian university. *Acta OrtopedicaBrasileira, 25*(2), 93-98. doi:10.1590/1413-785220172502165651

Clifton, D. R., Hertel, J., Onate, J. A., Currie, D. W., Pierpoint, L. A., Wasserman, E. B., . . . Kerr, Z. Y. (2018). The First Decade of Web-Based Sports Injury Surveillance: Descriptive Epidemiology of Injuries in US High School Girls' Basketball (2005-2006 Through 2013-2014) and National Collegiate Athletic Association Women's Basketball (2004-2005 Through 2013-2014). *Journal of Athletic Training, 53*(11), 1037-1048. doi:10.4085/1062-6050-150-17

Coppack, R.J., Etherington, J.& Wills, A.K. (2011) The effects of exercise for the prevention of overuse anterior knee pain. *The American Journal of Sports Medicine, 39*(5), 940–948.

Dai, B., Herman, D., Liu, H., Garrett, W. E., & Yu, B. (2012). Prevention of ACL Injury, Part II: Effects of ACL Injury Prevention Programs on Neuromuscular Risk Factors and Injury Rate. *Research in Sports Medicine, 20*(3-4), 198-222. doi:10.1080/15438627.2012.680987

Dai, B., Herman, D., Liu, H., Garrett, W. E., & Yu, B. (2012). Prevention of ACL Injury, Part II: Effects of ACL Injury Prevention Programs on Neuromuscular Risk Factors and Injury Rate. *Research in Sports Medicine, 20*(3-4), 198-222. doi:10.1080/15438627.2012.680987

Ehrendorfer, S. (1998). Survey of sports injuries in physical education students participating in 13 sports. *Wiener KlinischeWochenschrift*,*110*(11), 397–400.

Emery, C. A., Cassidy, J. D., Klassen, T. P., Rosychuk, R. J., & Rowe, B. H. (2005). Effectiveness of a home-

based balance-training program in reducing sports-related injuries among healthy adolescents: a cluster randomized controlled trial. *Canadian Medical Association Journal, 172*(6), 749-754. doi:10.1503/cmaj.1040805

Emery, C. A., van den Berg, C., Richmond, S. A., Palacios-Derflingher, L., McKay, C. D., Doyle-Baker, P. K., . . . Hagel, B. E. (2020). Implementing a junior high school-based programme to reduce sports injuries through neuromuscular training (iSPRINT): a cluster randomised controlled trial (RCT). *British Journal of Sports Medicine, 54*(15), 913-+. doi:10.1136/bjsports-2019-101117

Faude, O., Rossler, R., Petushek, E. J., Roth, R., Zahner, L., & Donath, L. (2017). Neuromuscular Adaptations to Multimodal Injury Prevention Programs in Youth Sports: A Systematic Review with Meta-Analysis of Randomized Controlled Trials. *Frontiers in Physiology, 8*. doi:10.3389/fphys.2017.00791

Faude, O., Rossler, R., Petushek, E. J., Roth, R., Zahner, L., & Donath, L. (2017). Neuromuscular Adaptations to Multimodal Injury Prevention Programs in Youth Sports: A Systematic Review with Meta-Analysis of Randomized Controlled Trials. *Frontiers in Physiology, 8*. doi:10.3389/fphys.2017.00791

Flicinskiб J. (2008). Occurrence and risk factors of musculoskeletal pain and sport injuries in students of physical education in University of Szczecin. Annales Academiae*MedicaeStetinensis Journal, 54*(3), 31–47.

Fraser, M. A., Grooms, D. R., Guskiewicz, K. M., & Kerr, Z. Y. (2017). Ball-Contact Injuries in 11 National Collegiate Athletic Association Sports: The Injury Surveillance Program, 2009-2010 Through 2014-2015. Journal of Athletic Training, 52(7), 698-707. doi:10.4085/1062-6050-52.3.10 Kerr, Z. Y., Roos, K. G., Djoko, A., Dompier, T. P., & Marshall, S. W. (2017). Rankings of High School Sports Injury Rates Differ Based on Time Loss Assessments. *Clinical Journal of Sport Medicine, 27*(6), 548-551.

Gatt, C. J., Jr. (2014). Neuromuscular training for the prevention of ACL injuries: commentary on the article by Eric Swart, MD, et al.: "prevention and screening programs for anterior cruciate ligament injuries in young athletes: a cost-effectiveness analysis". *The Journal of bone and joint surgery. American volume, 96*(9), e77-e77. doi:10.2106/jbjs.n.00172

Gatt, C. J., Jr. (2014). Neuromuscular training for the prevention of ACL injuries: commentary on the article by Eric Swart, MD, et al.: "prevention and screening programs for anterior cruciate ligament injuries in young athletes: a cost-effectiveness analysis". *The Journal of bone and joint surgery. American volume, 96*(9), e77-e77. doi:10.2106/jbjs.n.00172

Goossens, L., De Ridder, R., Cardon, G., Witvrouw, E., Verrelst, R., & De Clercq, D. (2019). Injury prevention in physical education teacher education students: Lessons from sports. A systematic review. *European Physical Education Review, 25*(1), 156-173. doi:10.1177/1356336x17711675

Hochholzer, T., &Schoffl, V. R. (2005). Epiphyseal fractures of the finger middle joints in young sport climbers. *Wilderness & Environmental Medicine, 16*(3), 139-142. doi:10.1580/pr15-04.1

Javier Robles-Palazon, F., &Sainz de Baranda, P. (2017). Neuromuscular training programs for the injury prevention in young athletes. A literature review. *Sport Tk-RevistaEuroamericana De Ciencias Del Deporte,6*(2), 115-125.

Javier Robles-Palazon, F., &Sainz de Baranda, P. (2017). Neuromuscular training programs for the injury prevention in young athletes. A literature review. *Sport Tk-RevistaEuroamericana De Ciencias Del Deporte, 6*(2), 115-125.

Jones, G., & Johnson, M. I. (2016). A Critical Review of the Incidence and Risk Factors for Finger Injuries in Rock Climbing. *Current Sports Medicine Reports, 15*(6), 400-409. doi:10.1249/jsr.0000000000000304

Knowles, S., Marshall, S.W., Guskiewicz, K.M. (2006). Estimating rates and risks in sports injury research, J AthlTrain, 41(2):207–215.

Kozin, S.V., Safronov, D.V., Kozina, Z.L., Kniaz, H.O., Proskurnia, O., Prontenko, K., Lahno, O., Goncharenko, V., Kholodniy, A. (2020). Comparative biomechanical characteristics of one-arm hang in climbing for beginners and qualified athletes, ActaBioengBiomech., 22(1), 57-67. DOI: 10.37190/ABB-01440-2019-03.

Kozin, S. (2019), Biomechanical substantiation of the technique of hanging in rock climbing, Health, sport, rehabilitation, 5(1), 25-35. DOI: 10.34142/HSR.2019.05.01.03.

Kozin,S., Cretu,M., Kozina,Z., Charnozub,A., Ryepko, O., Shepelenko,T., Iryna Sobko, I., Oleksiuk,M. (2021). Application closed kinematic chain exercises with eccentric and strength exercises for the shoulder injuries prevention in studentrock climbers: a randomized controlled trial. ActaBioengBiomech, 23(2), 54-62. DOI: 10.37190/ABB-01828-2021-01

Kozina, Z., Repko, O., Kozin, S., Kostyrko, A., Yermakova, T., Goncharenko, V. (2016). Motor skills formation technique in 6 to 7-year-old children based on their psychological and physical features (rock climbing as an example). *Journal of Physical Education and Sport, 16*(3), 866-874. doi:10.7752/jpes.2016.0313

Kozina, Z., Uvarova, N., Cieslicka, M., et. al. (2020a). Experimental substantiation of the program of the annual cycle preparation of climbers 16-17 year to the discipline “Climbing Combined”.*Journal of Physical Education and Sport, 20* (4), 1250- 1256. DOI:10.7752/jpes.2020.s2174.

Kozina, Z., Uvarova, N., Kniaz, H., et. al. (2020b). The influence of results in various types of climbing on the result in the Olympic Climbing Combined at the 2018 World Cup (men). *Journal of Physical Education and Sport, 20* (1), 255 - 261. DOI:10.7752/jpes.2020.01034.

LaBella, C.R., Huxford, M.R., Grissom, J, et al. (2011). Effect of neuromuscular warm-up on injuries in female soccer and basketball athletes in urban public high schools. *Archives of Pediatrics and Adolescent Medicine, 165(*11), 1033–1040.

Lutter, C., El-Sheikh, Y., Schoffl, I., &Schoffl, V. (2017). Sport climbing: medical considerations for this new Olympic discipline. *British Journal of Sports Medicine, 51*(1), 2-U5. doi:10.1136/bjsports-2016-096871

Lynall, R. C., Gardner, E. C., Paolucci, J., Currie, D. W., Knowles, S. B., Pierpoint, L. A., . . . Kerr, Z. Y. (2018). The First Decade of Web-Based Sports Injury Surveillance: Descriptive Epidemiology of Injuries in US High School Girls' Field Hockey (2008-2009 Through 2013-2014) and National Collegiate Athletic Association Women's Field Hockey (2004-2005 Through 2013-2014). *Journal of Athletic Training, 53*(10), 938-949. doi:10.4085/1062-6050-173-17

Lysens, R.J., Michel, S., Ostyn, M.D., et al. (1989). The accident-prone and overuse-prone profiles of the young athlete. The American Journal of Sports Medicine 17(5): 612–619. Ma¨kela¨ K and Hirvensalo M (2015) Work ability of Finnish physical education teachers. *The Physical Educator*, 72, 379–393.

Martinez-de-Quel-Perez, O., Sanchez-Moreno, A., Zamorano-Feijoo, C., &Ayan-Perez, C. (2019). SPORT INJURIES IN SCHOOL AND EXTRACURRICULAR ACTIVITIES IN THE COMMUNITY OF MADRID (SPAIN). *RevistaInternacional De Medicina Y Ciencias De La ActividadFisica Y Del Deporte, 19*(73), 151-166. doi:10.15366/rimcafd2019.73.011

McCann, R., Cortes, N., Van Lunen, B., Greska, E., Ringleb, S., & Onate, J. (2011). Neuromuscular Changes Following an Injury Prevention Program for ACL Injuries. *International Journal of Athletic Therapy & Training, 16*(4), 16-20. doi:10.1123/ijatt.16.4.16

McLoughlin, R. J., Green, J., Nazarey, P. P., Hirsh, M. P., Cleary, M., &Aidlen, J. T. (2019). The risk of snow sport injury in pediatric patients. *American Journal of Emergency Medicine, 37*(3), 439-443. doi:10.1016/j.ajem.2018.06.006

Owoeye, O. B. A., Emery, C. A., Befus, K., Palacios-Derflingher, L., &Pasanen, K. (2020). How much, how often, how well? Adherence to a neuromuscular training warm-up injury prevention program in youth basketball. *Journal of Sports Sciences, 38*(20), 2329-2337. doi:10.1080/02640414.2020.1782578

Owoeye, O. B. A., Emery, C. A., Befus, K., Palacios-Derflingher, L., &Pasanen, K. (2020). How much, how often, how well? Adherence to a neuromuscular training warm-up injury prevention program in youth basketball. *Journal of Sports Sciences, 38*(20), 2329-2337. doi:10.1080/02640414.2020.1782578

Owoeye, O. B. A., Palacios-Derflingher, L. M., & Emery, C. A. (2018). Prevention of Ankle Sprain Injuries in Youth Soccer and Basketball: Effectiveness of a Neuromuscular Training Program and Examining Risk Factors. *Clinical Journal of Sport Medicine, 28*(4), 325-331. doi:10.1097/jsm.0000000000000462

Owoeye, O. B. A., Palacios-Derflingher, L. M., & Emery, C. A. (2018). Prevention of Ankle Sprain Injuries in Youth Soccer and Basketball: Effectiveness of a Neuromuscular Training Program and Examining Risk Factors. *Clinical Journal of Sport Medicine, 28*(4), 325-331. doi:10.1097/jsm.0000000000000462

Parkkari, J., Taanila, H., Suni, J, et al. (2011). Neuromuscular training with injury prevention counseling to decrease the risk of acute musculoskeletal injury in young men during military service: a populationbased, randomized study. *BMC Medicine, 9*(1), 35.

Pasanen, K., Parkkari, J., Pasanen, M., et al. (2008). Neuromuscular training and the risk of leg injuries in female floorball players: cluster randomised controlled study. *British Journal of Sports Medicine,*42, 802–805.

RahlfAugustsson, J., Esko, A., Thomee, R., &Svantesson, U. (1998). Weight training of the thigh muscles using closed vs. open kinetic chain exercises: A comparison of performance enhancement. *Journal of Orthopaedic & Sports Physical Therapy, 27*(1), 3-8. doi:10.2519/jospt.1998.27.1.3

Rahlf, A. L., John, C., Hamacher, D., &Zech, A. (2020). Effects of a 10 vs. 20-Min Injury Prevention Program on Neuromuscular and Functional Performance in Adolescent Football Players. *Frontiers in Physiology, 11*. doi:10.3389/fphys.2020.578866

Rahlf, A. L., John, C., Hamacher, D., &Zech, A. (2020). Effects of a 10 vs. 20-Min Injury Prevention Program on Neuromuscular and Functional Performance in Adolescent Football Players. *Frontiers in Physiology, 11*. doi:10.3389/fphys.2020.578866

Russell, K., Selci, E., Black, B., Cochrane, K., & Ellis, M. (2019). Academic outcomes following adolescent sport-related concussion or fracture injury: A prospective cohort study. Plos One, 14(4). doi:10.1371/journal.pone.0215900

Sang, M. X. (2019). Analysis on the Causes of Sports Injury in College Physical Education and Its Prevention Strategies. Slater, L. V., Wasserman, E. B., & Hart, J. M. (2019). Trends in Recurrent Anterior Cruciate Ligament Injuries Differ From New Anterior Cruciate Ligament Injuries in College and High School Sports: 2009-2010 Through 2016-2017. Orthopaedic Journal of Sports Medicine, 7(11). doi:10.1177/2325967119883867

Schoffl, V., Popp, D., Kupper, T., &Schoffl, I. (2015a). Injury Trends in Rock Climbers: Evaluation of a Case

Series of 911 Injuries Between 2009 and 2012. *Wilderness & Environmental Medicine, 26*(1), 62-67. doi:10.1016/j.wem.2014.08.013

Silvers-Granelli, H. J., Bizzini, M., Arundale, A., Mandelbaum, B. R., & Snyder-Mackler, L. (2018). Higher compliance to a neuromuscular injury prevention program improves overall injury rate in male football players. *Knee Surgery Sports Traumatology Arthroscopy, 26*(7), 1975-1983. doi:10.1007/s00167-018-4895-5

Silvers-Granelli, H. J., Bizzini, M., Arundale, A., Mandelbaum, B. R., & Snyder-Mackler, L. (2018). Higher compliance to a neuromuscular injury prevention program improves overall injury rate in male football players. *Knee Surgery Sports Traumatology Arthroscopy, 26*(7), 1975-1983. doi:10.1007/s00167-018-4895-5

Sommerfield, L. M., Harrison, C. B., Whatman, C. S., &Maulder, P. S. (2020). A prospective study of sport injuries in youth females. Physical Therapy in Sport, 44, 24-32. doi:10.1016/j.ptsp.2020.04.005

Steffen, K., Emery, C. A., Romiti, M., Kang, J., Bizzini, M., Dvorak, J., . . . Meeuwisse, W. H. (2013). High adherence to a neuromuscular injury prevention programme (FIFA 11+) improves functional balance and reduces injury risk in Canadian youth female football players: a cluster randomised trial. *British Journal of Sports Medicine, 47*(12), 794-+. doi:10.1136/bjsports-2012-091886

Steffen, K., Emery, C. A., Romiti, M., Kang, J., Bizzini, M., Dvorak, J., . . . Meeuwisse, W. H. (2013). High adherence to a neuromuscular injury prevention programme (FIFA 11+) improves functional balance and reduces injury risk in Canadian youth female football players: a cluster randomised trial. *British Journal of Sports Medicine, 47*(12), 794-+. doi:10.1136/bjsports-2012-091886

Sugimoto, D., Alentorn-Geli, E., Mendiguchia, J., Samuelsson, K., Karlsson, J., & Myer, G. D. (2015). Biomechanical and Neuromuscular Characteristics of Male Athletes: Implications for the Development of Anterior Cruciate Ligament Injury Prevention Programs. *Sports Medicine, 45(*6), 809-822. doi:10.1007/s40279-015-0311-1

Sugimoto, D., Alentorn-Geli, E., Mendiguchia, J., Samuelsson, K., Karlsson, J., & Myer, G. D. (2015). Biomechanical and Neuromuscular Characteristics of Male Athletes: Implications for the Development of Anterior Cruciate Ligament Injury Prevention Programs. *Sports Medicine, 45*(6), 809-822. doi:10.1007/s40279-015-0311-1

Woollings, K. Y., McKay, C. D., Kang, J., Meeuwisse, W. H., & Emery, C. A. (2015). Incidence, mechanism and risk factors for injury in youth rock climbers. *British Journal of Sports Medicine, 49*(1), 44-50. doi:10.1136/bjsports