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Monitoring and Prevention of Lower Limb Joints Overload and Injuries in Athletes Aged 13-18 Representing Dynamic Sports - Project

Andrzej Czamara

The College of Physiotherapy in Wrocław, Tadeusza Kościuszki St. 4, 50-038 Wrocław, Poland, Tel: +48 606 246 746

Abstract

The number of lower limbs joint injuries in young athletes is increasing. Individual and group assessment of joint overloads and lower limb injuries in 400 young athletes every year for four years, who will be divided according to gender, sports disciplines, aged 13 to 18 years and an assessment of their developmental age and if necessary, individual compensatory intervention programs can be carried out. Body posture, patella mobility, fascial tension, balance, pain by Visual Analog Scale, level of physical activity by Tegner Activity Scale (TAS), International Knee Documentation Committee Scale (IKDC), modified Tampa Scale of Kinesiophobia (TSK-11) will be assess. Range of motion in joints (°), joint and thigh circumferences and length of lower limbs (cm), mobility deficits in the finger-floor and Patrick's test (cm), hamstring contractures, squat (°), running time at maximum speed and changes in the direction of maneuvers over a distance of double envelope 5 x 5 meters (s). The Maximum Isometric Torque (IT), Isokinetic Torque (PT) measures for extensor and knee flexors in (N*m) for 180 and 60 °/s will be introduced. They Lower Limb Power (W), jump height (cm), vertical components of Ground Reaction Forces (v GRF) during vertical jumps, downward jumps and repeated jumps on two and single legs will be measured (N) also their Lateral Symmetry Index. If risks of biomechanical disorders, physical fitness or motor coordination are identified, compensatory exercises program will be introduced for each athlete, and if there are clinical indications, the specialist medical doctor will make further decisions. **Keywords:** Clinical tests; Biomechanics; Physical fitness; Compensatory exercises; Education; Psychology; Gender

Abbreviations: ACL: Anterior Cruciate Ligament; CMJ: Counter Movement Jump; DJ: Drop Jump; FAAM: Foot and Ankle Ability Measure Scale; IKDC: International Knee Documentation Committee Scale; IT: Isometric Torque; LSI: Lateral Symmetry

Index; MHHS: Modified Harris Hip Score; PT: Peak Torque; TAS: Tegner Activity Scale; TSK-11: Tamp Scale of Kinesiophobia; VAS: Visual Analog Scale; vGRF: vertical component Ground Reaction Forces

Introduction

In the last two decades, the number of overloads and injuries of the lower limb joints in young athletes has been increasing. The problem is especially true for the knee and ankle joints in teenagers practicing sports with high loads, exercise intensity, jumps, falls and dynamic rotations, running at maximum speed and with rapid changes in direction. The studies suggest a relationship between gender, the developmental age of children and adolescents, stages of physiological development and the risk of damage to the knee joint, especially its ligaments. Under the age of 12, a higher proportion of Anterior Cruciate Ligament (ACL) injuries to the knee joints were reported in physically active boys, and more of these injuries were reported in physically active girls during adolescence between the ages of 12 and 16. In both sexes, the rate of knee injuries increases and is highest between the ages of 15 and 18 [1-8]. Internal factors predisposing to overloads and injuries of the musculoskeletal system include developmental age dynamics, sexual dimorphism, anatomical changes and anthropometric determinants of developmental age, changes in the physiology of development of adolescents and hormonal changes during puberty. Psychological problems of a maturing athlete, body biomechanics, problems with neuromuscular coordination of the musculoskeletal system, which in certain conditions predisposes to injuries of the lower limbs are also important [1,4]. External factors that increase the risk of the lower limbs joint injuries are mainly early sports specialization, problems with education programs in kindergartens, primary and secondary schools and a high level of sports competition, high frequency of training and competitions of young athletes, a large volume of sports loads [9]. Other risk factors for lower limb injuries include too short recovery time in young people practicing sports [4,10]. A similar position was presented by other authors [11-15]. The type and quality of the substrate for sports activity are important factors that may affect the increasing risk of overload and injuries of the musculoskeletal system, as well as the footwear used, thermal conditions, lack of warm-up, lack of comprehensive general development training appropriate to the developmental age, and previous injuries of the musculoskeletal system [16-20]. The highest number of injuries recorded among high school students (31%) and most injuries (45%) occurred during football competitions [21]. Deficit of quadriceps muscle strength, low performance of one-legged jumps and lack of mental and emotional readiness of the athlete for sports, promotes ACL damage and may be the reason for re-damage to knee joint after the primary treatment in young athletes [22]. Subsequently, biomechanical disorders of the hamstrings muscles in relation to the extensor muscles of the knee joint, overload and damage to these muscles are common among young athletes practicing dynamic sports, especially during sprinting

[23]. Excessive asymmetry of different biomechanical parameters values between the lower limbs during various sports activities impaired indicators of reactive force and times of contact of the feet with the ground during various jumps, disorders of neuromuscular control, may promote the occurrence of overloads and may lead to the knee and ankle joints injuries in young athletes during sports competition, which is particularly visible between the ages of 15 and 18 [9,10,21,24,25]. Therefore, the author of the planned research proposes to introduce a program of

monitoring and prevention overloads and injuries of the lower limbs joints from a medical, sports, biomechanical, neuro-muscular and psychological, also from an educational point of view [26-29].

The main objective of the research will be an individual and group statistical assessment of overload and injuries of the joints of the lower limbs in 400 young athletes divided by gender, various dynamic sports disciplines and age from 13 to 18 years of representatives at the level of at least Lower Silesia. The specific objectives - introduction of compensatory training or therapeutic exercises for young athletes who have experienced disorders of joint function, biomechanical parameters of the lower limbs or neuromuscular coordination - obtain reference data for gender, sports disciplines, adequate to the developmental age between 13 and 18 years in young athletes.

Material

The project will be carried out over 4 years. Every year, we will conduct research for 400 young athletes between 13 to 18, including young women and men practicing sports disciplines with an increased risk of lower limb injuries. It was assumed that 20 to 40% of the athletes surveyed out of an initial group of 400 people would complete 4 studies. Therefore, new athletes will be recruited every year to ensure the number of 400 participants per year. The final number of participants over the 4 years of the project will approach a minimum of 1000 people. The study is part of a public research (grant no. DR-S/401/2024) proposed by the author of this manuscript and is funded by the Lower Silesian Voivodeship Self Government. All procedures will be in accordance with the Declaration of Helsinki and have been approved by the Ethics Committee of the College of Physiotherapy in Wroclaw, Poland (Approval No. 1/7/2024, 26 July 2024).

Inclusion criteria for the study: A person has permission from a licensed medical doctor to play sports. Sports level of at least 8 on the Tegner Activity Scale and higher [30]. Each athlete represents at least the Lower Silesian Voivodeship and practices at least one of the sports disciplines, such as football, volleyball, basketball, handball, martial arts, badminton, speed skating, downhill skiing. Consent to conduct tests is required, and in the case of minors, the consent of their legal guardians. The participant will undergo medical prequalification on the day of the exam to rule out contraindications.

Methods

I. We will analyze the medical documentation and ask the athlete and the parents (if the athlete is a minor) about possible injuries and diseases of the lower limbs. If the athlete has undergone treatment of the lower limbs, we note the medical diagnosis, the type and method of treatment (conservative, surgical, other), immobilization of the lower limb, crutches or other orthopedic equipment, the time of the recommended relief of the lower limb. We will determine whether the athlete has undergone physiotherapy, its protocol and the time of this therapy. We will determine when the athlete returned to training and then to sports competition from the injury. We will ask the athlete and/or the parent of a minor if they need additional consultation, help from a sports medicine specialist, psychologist or pedagogue, who are provided for in the project.

II. Subjective assessment expressed by the respondents in accordance with rating scales:

A. Assessment of the level of sports activity according to the 10-point Tegner Activity Scale (TAS) [30].

B. Modified 11-elements Tampa Scale of Kinesiophobia (TSK-11) [31].

C. Pain by standard Visual Analog Scale (VAS) [32].

D. The International Knee Documentation Committee Score (IKDC) [33-36].

E. Additionally, the Foot and Ankle Ability Measure Scale (FAAM) if the subject was treated for an ankle injury [37-39] or Modified Harris Hip Score/ Hip Outcome Score if the subject was treated for a hip injury [40].

III. Measurement and evaluation of results obtained during standard tests (Figure 1): 1a. We will determine the age of the test subject (years), measure the values of body mass (kg) and body height (cm) and calculate the percentage (%) of Body Mass Index (BMI)

1b. Active range of motion of knee joints extension (º)

1c. Active range of motion of knees joints flexion (º)

1d. Limb lengths (cm)

1e. Knee joints circumference (cm)

1f. Quadriceps thigh muscles circumference (cm)

1g. Finger-floor test (cm)

1h. Patrick test (cm)

1i. Hamstring muscles contracture test (º)

1j. Squat with both legs in full contact of the feet with the ground (º)

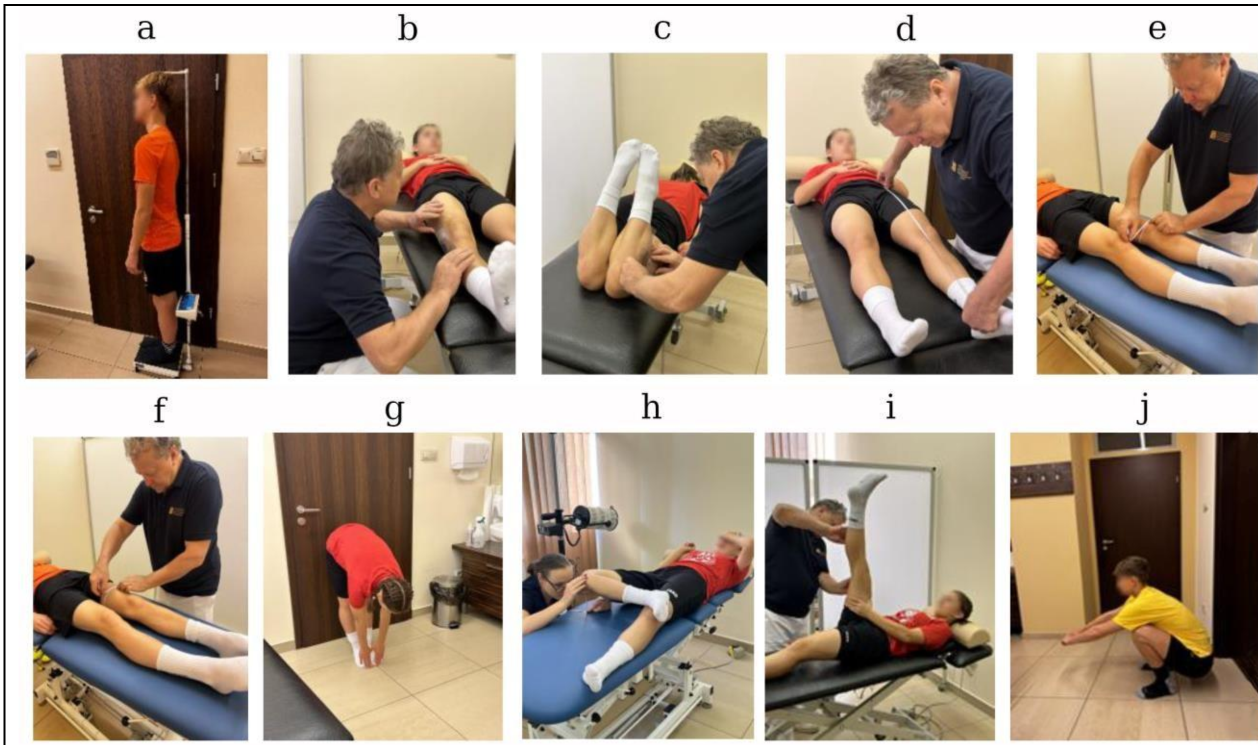

Figure 1(a-j): Measurement and evaluation of the results obtained during standard tests.

IV. The Evaluation of the Standard Functional Tests Shown in (Figure 2)

2a. Body posture, arches of the foot

2b. Patellofemoral joint mobility and fascial tension 2c. Standing on one leg and keeping balance (eyes opened and eyes closed) 2d. Strength of the gluteus maximus muscles

2e. Walking on flat ground at a distance of 10 meters

2f. Going up and down stairs at a distance of 10 steps

2g. Going very slowly down the stairs step by step (8 seconds) at a distance of 4 steps of stairs. If the examiner sees disturbances or failure to maintain the balance and stability of the supporting limb in the eccentric phase during a slow stair step, we will introduce Surface Electromyography (sEMG) to monitor possible disorders of muscle tone control for quadriceps thigh muscles.

Additionally, if the athlete has suffered an ankle and/or hip injury that required treatment, we will additionally carry out measurements and tests; The active range of motion of the ankle joints (º), their circumferences and we will assess the strength of the triceps calf muscles, successively mm. Dorsal flexors of the feet and a climbing test will be carried out on the toes of the left and right foot. Similarly, in the case of a hip injury, measurements of ranges of motion and assessment of the strength of the hip girdle muscles will be performed.

Figure 2 (a-g): Assessment of standard functional test results.

V. Measurement of Biomechanical Parameter Values (Figure 3)

A.12-minute warm-up was performed prior to the start of biomechanical testing **(Figure 3a)** in accordance with the procedure described **[41].** Next, the test subject will be instructed on how to perform the test, a mock test will be carried out and the appropriate measurements and tests will be carried out in turn. There will be rest breaks of 3 to 5 minutes between the planned various biomechanical measurements and physical fitness tests.

B. Maximum Isometric Torque (IT) for extensor muscles of the knees (knee flexion angle 70 º), which is shown in **Figure 3b1** and for flexor muscles of the knees (knee flexion angle 30 º), which shows **Figure 3b2** in accordance with the previously described methodology **[42]** measured in Newton Meters (N*m).

C. Measurement of the maximum Peak Torque (PT) values measured in (N*m) during the isokinetic test of the extensor and flexor muscles of the knee joints **(Figure 3c1)** for angular velocities per second (180 º/s and 60 º/s) and a sample report of individual test results **(Figure 3c2)** according to the test methodology **[43]** with subsequent final modifications and with the possibility of analysis of other biomechanical parameters of the tested muscles **[41].**

D. Lower limb power (W), maximum vertical jumps height and vertical component of Ground Reaction Forces (v GRF) measured in Newtons (N) for different phases of maximum vertical Jump – Counter Movement Jump (CMJ) and other biomechanical parameters. The CMJ test consists of two series of five jumps each. Each attempt will be started from an upright standing position, with their hands placed on their hips. The width of the foot will be individually selected to ensure stability and optimal conditions for the jump. On the "start" command, the participant will perform the maximum vertical jump with both legs, keeping their hands on their hips for the entire duration of the movement. Subjects will be instructed to land as quietly as possible and to maintain a stable position for at least three seconds. Samples that do not meet these criteria will be excluded from further analysis. For further analysis, the result in which the athlete achieved the highest jump height will be selected and the values of power (W), jump height (cm) and v GRF (N) divided by the value of body mass (kg/bm) will be analysed, obtaining the relative values of vertical Ground Reaction Forces (R vGRF) expressed in Newtons per kilogram of body mass (N/kg bm) and the average values of these forces obtained from all of 10 repetitions for 3 specific phases of maximum vertical jumps (braking – eccentric - **Figure 3d1**, propulsion and flight - **Figure 3d2** and landing phase - **Figure 3d3**).

E. Reactive force (N) of the lower limbs during Drop Jump (DJ) test will be carried out according to an analogous organizational chart as the CMJ, including the stage of instruction, learning and trial jumps. The correct measurement will be taken after making sure that the participant has mastered the correct jumping technique. Competitors will jump from a platform 30 cm high, with their hands placed on their hips **(Figure 3e1).** After jumping on the platform **(Figure 3e2),** they will be tasked with making an immediate, maximally high vertical jump upwards **(Figure 3e3),** while striving for the shortest possible contact time with the ground. The requirements for landing technique and final position stabilization were identical to those in the CMJ test **(Figure 3e4).** The DJ test will be conducted in two sets of three jumps in each series.

F. Vertical component of Ground Reaction Forces (v GRF) during repeated double legged **(Figure 3f1)** and one-legged jumps (N) on the left **(Figure 3f2)** and separately on the right lower limb **(Figure 3f3)** and the test report **(Figure 3f4)** according to the methodology of the study **[44]** and finally according to the modified protocol of this study **[45].**

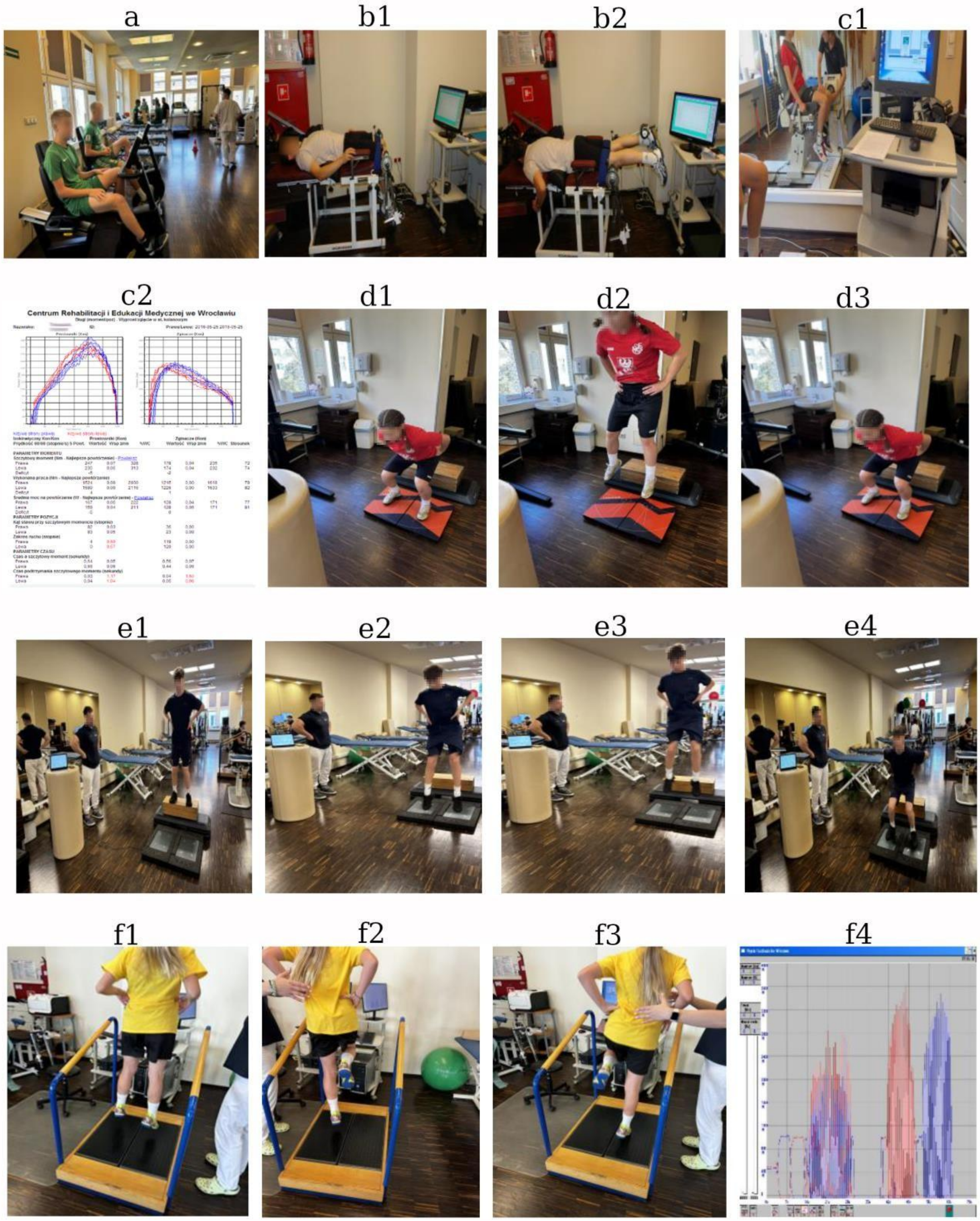

Figure 3(a-f): Measurement of biomechanical parameter values.

VI. Measurement of Specific Motor Skills of the Tested Athletes

A. Running time (s) at maximum speed and changes in direction over a distance of a double envelope of 5 x 5 meters (s) [46].

B. Maximum reach jumps for right and left limbs (cm).

C. A dedicated test for a specific sport proposed by the coach.

D. Evaluation of sports results achieved in the last and current year.

VII. The Research Team

The research team will be made up of professionals with academic and extensive clinical experience, including two doctors of medicine, specialists in orthopedics and traumatology and sports medicine, also a full professor of physiotherapy and 10 physiotherapists, a psychologist, a psycho- dietician, one motor preparation trainer, a pedagogue and also a professor of medical statistics.

VIII. Planned Statistical Analyses

All statistical analyses will be carried out using the Python programming language and dedicated libraries. For quantitative variables, descriptive statistics will be calculated: arithmetic mean (Mean), Standard Deviation (SD), median (Me), range (Min– Max) and quartiles (Q1–Q3). The normality of the distribution will be verified using the Shapiro–Wilk test. Differences between the two groups (e.g. gender) will be analysed using the t-Student test for independent samples or the Mann–Whitney U test in the case of a violation of the assumptions of normality. For comparisons between the three categories - groups, the analysis of the ANOVA variance from post hoc or the Kruskal–Wallis test will be used. A p value < 0.05 will be considered statistically significant. The relationships between variables, e.g. relative variables and asymmetry indices of the studied parameters will be analysed using the Spearman rank correlation coefficient (r). In order to identify significant predictors of the dependent variable, linear regression analysis will be performed using the stepwise method. Demographic variables (e.g. gender, age, sport) and biomechanical indicators in values converted to kg of body mass will be included in the model, the so-called relative values and the level of asymmetry. The significance of predictors (p), values of standardized beta coefficient (β), coefficients of determination (R^2 and Adj R^2), t statistics and the level of collinearity (VIF) will be evaluated.

Discussion

Expected research results, possible limitations: On the basis of individual examinations carried out once a year and for the next four years of the planned project, a protocol and report will be prepared annually for each young athlete examined, with the additional obligation to inform the parent of the underage athlete and, after the parent of the underage athlete expresses it, this information will be provided to the coach and other members of the sports and medical teams of the club or national team. The report will present a comprehensive analysis, evaluation, suggestions and proposals on how to direct, improve and adapt the individual preparation of the athlete for the needs of the sport, also taking into account the developmental age, gender and at the same time take care of the health of the surveyed young people practicing sports at a professional level. After discussing and submitting the protocol of individual test research, the examination team will conduct practical instructions for each tested athlete on what additional individual compensatory exercises should be introduced and other health-promoting activities (the report also includes this information for parents of underage athletes). Every parent and coach will be able to participate in the tests. In addition, club and national team coaches, doctors, physiotherapists, psychologists and other employees dealing with young athletes will participate in special trainings, conferences and workshops to implement individual compensatory exercise programs and obtain more information from medical doctors, physiotherapists, and at the same time a motor preparation coach, as well as from a psychologist, psycho-dietician or statistician, who will conduct research. The participation of the planned voivodeship sports teams, including coaches, players, parents and their medical teams, will be free of charge. Training participants will be informed about the behaviour of various anthropometric parameters, flexibility, assessment of body posture, physical fitness, coordination of movement and a whole range of biomechanical analyses, lower limbs and the entire locomotor system, motor skills of competitors during the performance of various specific motor tasks and their physical fitness values. Effect of these trainings will be to prepared coaches and other participants of these trainings in order to support young athletes in the educational field about possible threats, avoiding overloads of the musculoskeletal system, the role of body regeneration, emotional development, psychological state and possible fears of risk factors for injuries to the musculoskeletal system and itself and the need to assess and monitor the mobility and physical fitness of young athletes. Educational materials and directional publications will be prepared. Every year and consecutively, on the basis of four years of research, the level of possible overload and dysfunction of the lower limb joints in young athletes aged 13 to 18 who practice dynamic sports disciplines will be assessed, as well as compensatory exercise programs for young athletes will be described. In addition, the obtained data from the research are expected to provide an answer on the behaviour of values and the direction of development of various parameters and characteristics studied for example; anthropometric, psychological, physical, motor, biomechanical and physical fitness and neuromuscular coordination of the musculoskeletal system as reference data for the developmental age, puberty process, gender and sports discipline of young athletes between the ages of 13 and 18, which may allow for the optimization of the training process. We hope that the proposed research program will contribute to reducing lower limb overloads and injuries in young athletes. Limitations of planned studies: We do not know how many young athletes will take part in the planned studies again within four years. We assume that 25 to 40% of the athletes surveyed out of an initial 400 people will complete 4 studies. We have another unknown, whether all our recommendations will be implemented in the process of training young athletes, which on the one hand we can check in the analysis of studies year after year, but will athletes who do not follow these recommendations take part in our next studies?. To limit the possible decline in the number of athletes surveyed over the next four years compared to the original 400 people, we will recruit up to 400 athletes per year free of charge to get as much information as possible about their development of young athletes between the ages of 13 and 18, and we are also in talks with other universities and regions to increase the potential of the research.

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