Rehabilitation Protocol for Patellar Tendinopathy Applied Among 16- to 19-Year Old Volleyball Players

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Abstract

Biernat, R, Trzaskoma, Z, Trzaskoma, Ł, and Czaprowski, D. Rehabilitation protocol for patellar tendinopathy applied among 16- to 19-year old volleyball players. *J Strength Cond Res* 28 (1): 43–52, 2014—The aim of the study was to investigate the efficacy of rehabilitation protocol applied during competitive period for the treatment of patellar tendinopathy. A total of 28 male volleyball players were divided into two groups. Fifteen from experimental group (*E*) and 13 from control group (*C*) fulfilled the same tests 3 times: before the training program started (first measurement), after 12 weeks (second measurement) and after 24 weeks (third measurement). The above-mentioned protocol included the following: USG imagining with color Doppler function, clinical testing, pain intensity evaluation with VISA-P questionnaire, leg muscle strength and power and jumping ability measurements. The key element of the rehabilitation program was eccentric squat on decline board with additional unstable surface. The essential factor of the protocol was a set of preventive functional exercises, with focus on eccentric exercises of hamstrings. Patellar tendinopathy was observed in 18% of the tested young volleyball players. Implementation of the presented rehabilitation protocol with eccentric squat on decline board applied during sports season lowered the pain level of the young volleyball players. Presented rehabilitation protocol applied without interrupting the competitive period among young volleyball players together with functional exercises could be an effective method for the treatment of patellar tendinopathy.

Key Words patellar tendon, jumper's knee, strength and power, eccentric squat

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Introduction

Pathological lesions in tendons may be defined as syndrome, which includes pain in the tendon's area, often swelling and limited activity level (32). Clinical diagnosis is most frequently based on patients' subjective reports of pain. The pain during physical activity is the basic symptom. Most common location is the proximal patellar attachment, just under the apex of patella (27,35). In addition, tenderness during palpation the tendon confirms the diagnosis that can next be verified by USG or MRI (50). Blazina et al. (6) in 1973 as first described the syndrome of so-called jumper's knee as nonregressive idiopathic injury, the symptoms of which may continue for a long time with numerous recurrences despite implementation of various methods. So-called jumper's knee is a typical overload injury and can significantly lower the sports performance or even become the main reason of career disruption in sport (28,31,41,45).

Many risk factors influence the formation of degenerative changes in patellar tendon (20). These can be classified as external and internal (45). The first category includes incorrect sports training, when a large part and intensity of effort increases the risk of pathology. The surface on which the trainings and matches take place plays a vital role. Artificial hard surface negatively affects the load on patellar tendon (8,45). Insufficient technical preparation of sports people, incorrect proportions between training and rest time or inadequate equipment (i.e., worn out trainers that lost their shock absorbing properties) are other external factors. Internal factors include limited muscle flexibility. The most important muscles, in which the functional limitation of flexibility influences the origin of pathological changes in patellar tendon, are hamstrings and quadriceps (15,55). The limitation of dorsiflexion in the talocrural joint is also mentioned as one of the main reasons of patellar tendinopathy genesis (40). Because about 60% of values of ground reaction forces are absorbed only below the knee joint (15), disorders in the taloctrural joint (e.g., the mobility limitation or weakening of plantar flexors) change the proportions causing higher overload of structures within the area of knee joint. Further internal factors include biomechanical disorders, among others incorrect position of lower limb, i.e., valgus foot, so-called valgus or varus knee, tibia varus, patellar malalignment, hip anteversion, a significant leg length discrepancy, incorrect proportions between the strength of antagonistic muscles and the limited range of motion of the joints (15,40,45,48). Although there are no undoubtful proofs for the relation between biomechanical disorders and patellar tendinopathy, the correction is believed to be advisable. Also the revision of dynamic control and jumping technique (especially of the landing phase) are justified.

Currently, there are no doubts that in patellar tendinopathy, there are degenerative changes without inflammation within patellar tendon (26,30,39,44,45,51). If chronic may lead to it's rupture (42). Degenerative changes are connected with sports activity and their frequency is increasing with age. People above 25 years, whose tensile strength of the tendon diminished and its flexibility is lowered, are more prone to the injury (29,8). The research from recent years indicates the presence of ingrown neovessels in the pathologically changed tendons (1,2,12,37,43). The presence of ingrown neovessels seems to be more connected with pain than with the potential to the process of treatment (11). In tests when athletes underwent USG imaging with color Doppler function, it was verified that when neovessels were found, the pain symptoms of these athletes were stronger than among the athletes with morphologically changed tendons without neovessels (13,38). Currently, many researchers deal with the genesis of pain in tendon pathologies (1,2,14) and more of them connect pain with the presence of ingrown mechanoreceptors in pathologically changed tendons (3,11,13).

Patellar tendinopathy requires special care due to the fact that it is a strenuous long-term injury (52). The group of athletes characterized by the most frequent occurrence of this injury is volleyball players. According to various sources, in this group, the so-called jumper's knee affects from 38 to 50% of players (5,36). High jumping ability are more prone to the so-called jumper's knee because of greater values of ground reaction forces during the landing phase, exceeding body mass of the jumper by 4–5 times (8). One-third of volleyball players with patellar tendinopathy symptoms are unable to train sport throughout the period of at least 6 months. Although the pace of degenerative changes in the tendon may be significantly slowed down because of regular, controlled and diversified exercises, age remains a significant factor related with the origin of patellar tendinopathy. In the age range of 18–55, the number is growing, especially between 30 and 35 years. The first person to verify the existence of patellar tendinopathy among athletes in the age of 14–18 was Cook (10).

Morphologic evaluation of patellar tendon is usually done with USG imaging because patellar tendon is easy to assess by ultrasonography. Imaging of the tendon may help locate pathological changes precisely (23) and evaluate the progress after surgical treatment. The typical changes in the USG imaging of the tendon is local thickening, irregular structure of the tendon, hypoechogenic areas around the proximal attachment. The intensity of symptoms indicating patellar tendinopathy is described according to 4-degree scale by Blazina et al. (6), where the degrees mean as follows: (a) the pain occurs only after physical activity; (b) the pain occurs at the beginning of physical activity, disappears after warm-up and recurs with fatigue; (c) the pain occurs during rest and during physical activities; it negatively affects performance and (d) patellar tendon tear. Medical treatment in case of patellar tendinopathy and tendinopathy of other tendons is most often based on the methods of trials and failures. The basis of the treatment is controlled exercises because the tendon reacts to load with faster metabolic rate, which positively affects the treatment. When an athlete's strength training is intense, the cross section of the tendon increases (34). The exercises during which the muscles work in eccentric conditions are believed to be most efficient (4,18,28,33,46,58).

The protocol in case of patellar tendinopathy is long term and strenuous. Nowadays, it is believed to be one of

Table 1. Characteristics of the groups studied (mean ± *SD*).*

Variable	First measurement	Second measurement	Third measurement
E (*N* = 15)			
Age (yrs)	17.7 ± 0.7†	18.0 ± 0.7†	18.2 ± 0.7†‡
Body mass (kg)	79.8 ± 10.4†	80.0 ± 9.2†	80.8 ± 9.6†‡
Height (cm)	191.0 ± 7.2†	191.1 ± 7.1†	191.3 ± 7.0†‡
Body fat (%)	14.7 ± 3.0	13.9 ± 2.4	12.8 ± 2.6†‡
C (*N* = 13)			
Age (yrs)	16.5 ± 0.8	16.8 ± 0.8	17.0 ± 0.8‡
Body mass (kg)	71.5 ± 5.8	72.1 ± 6.0	73.8 ± 6.3‡
Height (cm)	184.8 ± 3.9	185.1 ± 4.0	185.8 ± 4.0‡
Body fat (%)	14.3 ± 3.0	14.4 ± 2.9	14.6 ± 3.0

*E = experimental group; *C* = control group.
†$p \leq 0.05$ with respect to group *C*.
‡$p \leq 0.05$ with respect to first measurement.

the most difficult tasks in sports medicine (56). Currently, the direction of the rehabilitation protocol is complex attitude to this injury with the leading role of strength training, the principles of which are adjusted to the contemporary level of knowledge. Among many applied rehabilitation protocols, it is difficult to indicate the best one (57) and their efficiency is assessed in the range from 50 to 100%.

Based on own experiments, Cook et al. (12) worked out indications for rehabilitation protocol in case of patellar tendinopathy. These include: plyometric exercises, exercises in closed kinetic chains, keeping aerobic capacity, functional (multiplanar) stretching of the inflexible muscles, continuation of rehabilitation protocol for 6–12 months after finishing basic rehabilitation phase and complex functional evaluation at the end of the basic rehabilitation protocol. Moderate pain during eccentric exercises is acceptable. In the VAS (0–10) scale, where 0 means no pain and 10 maximal pain which makes doing the exercises impossible, the acceptable level is 3–4 (4,18,45). To evaluate the pain in patellar tendinopathy, VISA-P questionnaire was created in La Trobe University (Australia) and it was approved as repetitive and reliable (19,49). Active players with diagnosed pathology of patellar tendon get on average 50–80 points (maximal value is 100 points) in VISA-P questionnaire (5).

Therefore, the aim of the study was to investigate the efficacy of original rehabilitation protocol applied during competitive period for the treatment of patellar tendinopathy. Searching for new effective methods possible to be applied during the season seems to be crucial for professional sport. Quick and successful therapy might be crucial for effective decrease of pain and inflammation without significant lost of sport-specific and physical status of a player.

Methods

Experimental Approach to the Problem

The purpose of this study was to verify the effect of immediate rehabilitation protocol including weight, eccentric exercise applied without interrupting the competitive period for volleyball players suffering patellar tendinopathy. The previous studies clearly presented possible changes expected after different training programs mostly performed separately from the sport-specific training. Our aim was to investigate the effectiveness of combined eccentric squat and functional physiotherapy exercises with specific volleyball training.

The participants were familiar with those training methods used in experiment, matched and randomized to 2 training groups, so that we could be sure that the changes were because of the different program and not because the subjects had a preference for that type of training.

Subjects

Two groups of male volleyball players, 16 people each, in the ages between 16 and 19 participated in tests. The basic criteria of inclusion to tests were as follows: ages between 16 and 19, systematic training and participation in volleyball matches. Fifteen players from the experimental group (*E*) and 13 from the control group (*C*) finished the tests. The volleyball players from both groups underwent the tests 3 times: before the beginning of training cycle (first measurement), after 12 weeks (second measurement) and after 24 weeks (third measurement). A written consent form was obtained from all subjects and their parents before participating and the study was approved by the local commission of ethics. All participants were also diagnosed by medical doctor, present during the measurements. The physical characteristics of the subjects are given in Table 1.

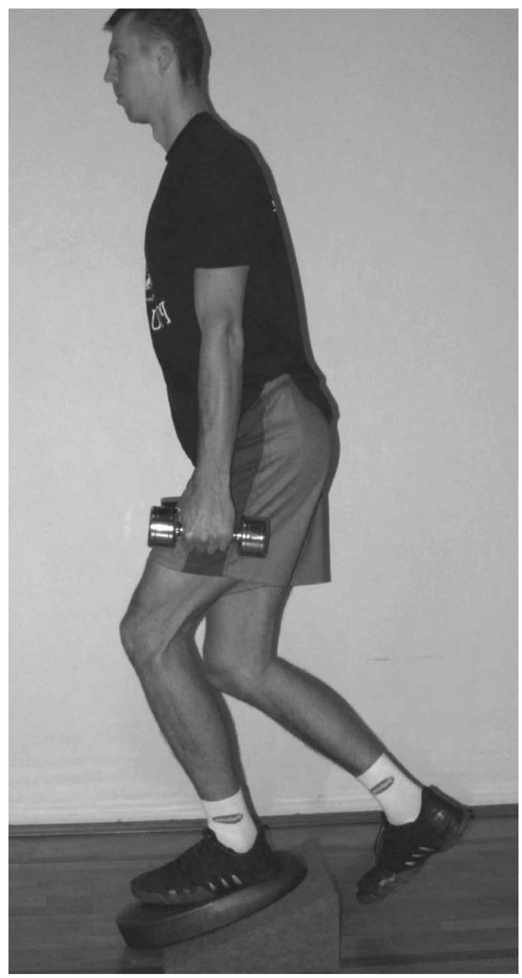

Figure 1. Eccentric squat on decline board on unstable surface with extra load.

Procedures

Training Program. The key element of our rehabilitation protocol was eccentric squat on decline board (Figure 1). The inclination angle was 25°. During the squat, the eccentric phase (lowering the center of the body mass) was done on 1 lower limb to the angle 60° of flexion in the knee joint similarly as in the protocol applied by Zwerver (59). The concentric phase of the squat (elevation of the body mass center) was done bilaterally to erect position. The tested athlete kept the trunk straight to limit influence of gluteus maximus. Inclination of the board limits the work of plantar flexors.

The players from the experimental group done the squats once a day, on the left and the right legs, in 3 series, 15 repetitions each. On the days when the volleyball players took part in matches or had intense trainings, the eccentric squats were not done. An extra element during eccentric squats introduced in the fourth week of the program was unstable surface, which increased the requirements of body stabilization and caused rotation in the knee joint during the squat.

Regarding the VAS scale (0–10 points), the exercises were done, when the level of pain did not exceed 4 points. In case of pain exaggeration, the exercise was not carried out. The load had to be lowered or the number of repetitions limited. Cold compresses were applied on patellar tendon after the exercise. The players done the eccentric squat on decline board during 24 weeks. Before the experiment started, each player was carefully instructed about strict rules to be kept during the eccentric squat on decline board. Experts in the field of functional training, such as Boyle (7), Cook (9), Gambetta (21), Goldenberg and Twist (25) and Radcliffe (47) underline the necessity of including these exercises into training programs because they lower the risk of injury. A wide range of functional exercises made a necessary element of our rehabilitation protocol. The main exercises applied to lower the risk of pathology of patellar tendon were hamstring eccentric exercises.

USG imaging with color Doppler function was done with the use of Vivid 4 device by General Electric (USA). All tests were supervised by 1 experienced medical doctor. USG imaging was done to specify structural changes within the tendon. The color Doppler function was used to verify the presence of neovessels in structures of the tendon. A 2-degree scale was used where 0–means lack of neovascularization and 1–means the presence of it in structure of the tendon.

The test with VISA-P questionnaire is used to evaluate the pain in patellar tedinopathy. This questionnaire was regarded as repetitive and reliable (19,49). Maximum score that can be achieved in this questionnaire is 100 points and it means that the tested person does not suffer from any pain symptoms or functional disorders and can participate in sports activities without limitations. Theoretical score of 0 points indicates maximal pain.

Muscle strength peak torque measurements of knee flexors and extensors under static and dynamic conditions (concentric activity under isokinetic conditions) were carried out with the use of BIODEX 3 Pro by Biodex Medical Systems

Table 2. Changes in mean (±*SD*) values of knee flexor and extensor force peak torques and hamstring to quadriceps ratio in tested groups (isometric contraction).*

Variable	First measurement	Second measurement	Third measurement
E (*N* = 15)			
L_{FLEx} (N·m)	165.1 ± 44.3†	174.1 ± 38.6†	169.1 ± 43.6†
$L_{FLEx/BW}$ (N·m·kg^{-1})	2.0 ± 0.4	2.2 ± 0.3‡	2.1 ± 0.4§
L_{ExT} (N·m)	310.9 ± 58.1†	334.4 ± 42.8†	299.7 ± 55.0†
$L_{ExT/BW}$ (N·m·kg^{-1})	3.9 ± 0.5	4.2 ± 0.4‡	3.7 ± 0.7§
$L_{FLEx/ExT}$ (%)	54.1 ± 14.7	52.4 ± 11.0	58.2 ± 19.6
R_{FLEx} (N·m)	178.2 ± 44.9†	183.7 ± 36.9†	171.3 ± 41.3†
$R_{FLEx/BW}$ (N·m·kg^{-1})	2.2 ± 0.4	2.3 ± 0.3	2.1 ± 0.3§
R_{ExT} (N·m)	313.8 ± 58.4	336.6 ± 48.4†	298.6 ± 72.1§
$R_{ExT/BW}$ (N·m·kg^{-1})	4.0 ± 0.7	4.2 ± 0.5‡	3.7 ± 0.9§
$R_{FLEx/ExT}$ (%)	57.8 ± 16.3	55.2 ± 12.0	55.1 ± 18.0
C (*N* = 13)			
L_{FLEx} (N·m)	136.8 ± 17.3	148.1 ± 22.1	143.1 ± 23.9
$L_{FLEx/BW}$ (N·m·kg^{-1})	1.9 ± 0.3	2.1 ± 0.3‡	1.9 ± 0.3§
L_{ExT} (N·m)	259.0 ± 40.5	278.9 ± 53.7	262.8 ± 34.5
$L_{ExT/BW}$ (N·m·kg^{-1})	3.6 ± 0.6	3.9 ± 0.7‡	3.6 ± 0.6§
$L_{FLEx/ExT}$ (%)	53.9 ± 10.1	54.8 ± 13.5	54.7 ± 8.8
R_{FLEx} (N·m)	144.1 ± 17.9	155.1 ± 20.3	148.6 ± 20.8
$R_{FLEx/BW}$ (N·m·kg^{-1})	2.0 ± 0.3	2.2 ± 0.3	2.0 ± 0.3§
R_{ExT} (N·m)	255.5 ± 44.9	270.7 ± 39.9	283.9 ± 30.6
$R_{ExT/BW}$ (N·m·kg^{-1})	3.6 ± 0.6	3.8 ± 0.6	32.9 ± 0.6
$R_{FLEx/ExT}$ (%)	57.3 ± 7.8	58.0 ± 8.2	52.5 ± 6.4

*E = experimental group; C = control group; right (*R*) and left (*L*) knee flexors and extensors = absolute (L_{FLEx}, L_{ExT}, R_{FLEx}, R_{ExT}) and relative values ($L_{FLEx/BW}$, $L_{ExT/BW}$, $R_{FLEx/BW}$, $R_{ExT/BW}$); hamstring to quadriceps ratio ($L_{FLEx/ExT}$ and $R_{FLEx/ExT}$).
†$p \leq 0.05$ with respect to group *C*.
‡$p \leq 0.05$ with respect to first measurement.
§$p \leq 0.05$ with respect to second measurement.

(USA). The measurements under static conditions for extensors at the angle of 70°, but for flexors at the angle of 30° in the knee joint. The measurements under dynamic conditions were carried out at 2 angular velocities of $90°\cdot s^{-1}$ and $240°\cdot s^{-1}$ (1,6 and 4,2 $rad\cdot s^{-1}$, respectively) in the range of knee motion from 90 to 0°. Each test was preceded by a 5-minute warm-up on cykloergometer and dynamic stretching of knee extensors and flexors. Each tested person was carefully instructed about the procedure of the test. The testing protocol included 3 repetitions, with 10-second breaks, for knee extensors and flexors under static conditions, 3 repetitions for muscles under dynamic conditions at the $90°\cdot s^{-1}$ and 5 repetitions at the $240°\cdot s^{-1}$ of angular velocity.

The measurements jumping ability and power of lower limbs during bilateral counter-movement jump akimbo (*CMJ akimbo*) were done on dynamometric platform PJS-4P by JBA (Poland). Each player jumped 3 times. The break between jumps was 5 seconds. The task was to reach maximum elevation of the center of the body mass, so-called height of the jump. The instruction was as follows: jump as high as you can! Maximum elevation of the body mass center and maximal power, reached in the best jump were measured (criterion–height of the jump).

Statistical Analyses

The measurements were analyzed with the use of Statistica 7.1. The evaluation of accordance of statistic layout of verified variables with the normal layout was carried out with Shapiro-Wilk's test. Significance of the differences between the average values of the analyzed variables for the experimental and control groups and the influence of the group and the following measurements on these differences, along with the interactions among the factors, were verified with the use of 2-factor analysis of variations for repetitive measurements of the analyzed variables, the statistic layout of which were not in accordance with normal layout, a nonparametric test was carried out (Wilcoxon's sequence of couples test). The agreed level of significance was $p \leq 0.05$.

Results

Considering the results of USG imaging in the experimental group it was verified:

1. the first measurements confirmed morphological changes within patellar tendon of 7 volleyball players, the second of 6 and third measurements of 5 players;
2. regarding first measurements, neovascularization occurred among 3 players, regarding the second in 2 players and, as it comes to third measurements–1 player.

In the control group:

1. the first measurements confirmed morphological changes of patellar tendon of 4 players, the second of 4 and third measurements of 3 volleyball players; regarding first measurements, neovascularization occurred in tendons of 3 volleyball players, regarding second of 2 players and, as it comes to third measurements–1 player.

Analyzing the results of USG imaging among volleyball players from both groups, the following was stated:

1. the percentage of players with morphological changes in the patellar tendon in first measurements was 40%, in second 36% and in third measurements 29%;

Table 3. Changes in mean (±*SD*) values of knee flexor and extensor force peak torques and hamstring to quadriceps ratio in tested groups (isokinetic contraction with angular velocity = 1.6 $rad\cdot s^{-1}$).*

Variable	First Measurement	Second Measurement	Third Measurement
E (*N* = 15)			
L_{FLEx} (N·m)	117.8 ± 26.5†	124.3 ± 25.0†	121.8 ± 24.8†
$L_{FLEx/BW}$ (N·m·kg^{-1})	1.5 ± 0.2	1.6 ± 0.2	1.5 ± 0.2
L_{ExT} (N·m)	214.7 ± 31.0†	233.3 ± 32.1†	222.7 ± 30.1†
$L_{ExT/BW}$ (N·m·kg^{-1})	2.7 ± 0.3	2.9 ± 0.3‡	2.8 ± 0.3§
$L_{FLEx/ExT}$ (%)	55.0 ± 10.0	53.5 ± 8.8	54.7 ± 8.8
R_{FLEx} (N·m)	126.7 ± 38.5†	131.9 ± 26.9†	127.5 ± 26.8†
$R_{FLEx/BW}$ (N·m·kg^{-1})	1.6 ± 0.4	1.6 ± 0.2	1.6 ± 0.2
R_{ExT} (N·m)	229.2 ± 40.6†	232.9 ± 34.2†	223.4 ± 42.1†
$R_{ExT/BW}$ (N·m·kg^{-1})	2.9 ± 0.3	2.9 ± 0.4	2.8 ± 0.5
$R_{FLEx/ExT}$ (%)	54.9 ± 11.7	57.4 ± 13.2	60.4 ± 25.7
C (*N* = 13)			
L_{FLEx} (N·m)	95.3 ± 15.6	103.4 ± 14.6	103.4 ± 14.6
$L_{FLEx/BW}$ (N·m·kg^{-1})	1.3 ± 0.2	1.4 ± 0.2‡	1.4 ± 0.2
L_{ExT} (N·m)	181.9 ± 27.9	189.7 ± 24.9	184.9 ± 27.6
$L_{ExT/BW}$ (N·m·kg^{-1})	2.6 ± 0.4	2.7 ± 0.4	2.5 ± 0.4
$L_{FLEx/ExT}$ (%)	52.6 ± 6.2	54.9 ± 7.3	56.5 ± 7.7
R_{FLEx} (N·m)	100.1 ± 15.0	109.9 ± 18.2	103.6 ± 18.4
$R_{FLEx/BW}$ (N·m·kg^{-1})	1.4 ± 0.2	1.5 ± 0.2‡	1.4 ± 0.2
R_{ExT} (N·m)	182.1 ± 31.8	201.1 ± 24.4	186.6 ± 31.6
$R_{ExT/BW}$ (N·m·kg^{-1})	2.6 ± 0.5	2.8 ± 0.4‡	2.5 ± 0.4§
$R_{FLEx/ExT}$ (%)	55.7 ± 7.3	54.8 ± 7.6	56.1 ± 8.9

*E = experimental group; C = control group; right (R) and left (L) knee flexors and extensors = absolute (L_{FLEx}, L_{ExT}, R_{FLEx}, R_{ExT}) and relative values ($L_{FLEx/BW}$, $L_{ExT/BW}$, $R_{FLEx/BW}$, $R_{ExT/BW}$); hamstring to quadriceps ratio ($L_{FLEx/ExT}$ and $R_{FLEx/ExT}$).
†$p \leq 0.05$ with respect to group C.
‡$p \leq 0.05$ with respect to first measurement.
§$p \leq 0.05$ with respect to second measurement.

2. the percentage of players with neovascularization in patellar tendon in first measurements was 21%, in second 14% and in the third measurements 7%.

Regarding the results of clinical tests carried out and evaluated by the same medical doctor in the experimental group, patellar tendinopathy symptoms were diagnosed in all measurements in reference to 3 players.

In the control group, clinical tests confirmed patellar tendinopathy symptoms among 2 players in first measurements, among 2 players in second (unable to continue trainings) and it concerned 1 player in the third measurements (unable to continue trainings).

Considering the results of clinical tests of the volleyball players from both groups, it was verified that:

1. the percentage of players with symptoms in first and second measurements was up to 18% and in the third measurements–14%;
2. in the age range of 16–17 years, 1 player was diagnosed as having symptoms of patellar tendinopathy;
3. in the age range of 17–19 years, 4 players were diagnosed as having patellar tendinopathy;
4. in the group of tested players, patellar tendinopathy referred 3 left limbs and 2 right limbs during the first measurements.

No significant differences were found between the 2 groups, in reference to both muscle torques measurement of knee flexors and extensors (relative values), and the "flexors-extensors" ratio, under isometric and isotonic conditions. The changes of maximal strength during the testing

Table 4. Changes in mean (±*SD*) values of knee flexor and extensor force peak torques and hamstring to quadriceps ratio in tested groups (isokinetic contraction with angular velocity = 4.2 rad·s^{-1}).*

Variable	First measurement	Second measurement	Third measurement
E (*N* = 15)			
L_{FLEx} (N·m)	108.2 ± 27.3†	107.2 ± 26.1†	103.1 ± 21.5†
$L_{FLEx/BW}$ (N·m·kg^{-1})	1.3 ± 0.3	1.3 ± 0.3	1.3 ± 0.2
L_{ExT} (N·m)	148.6 ± 25.5†	161.3 ± 26.5†	155.6 ± 23.2†
$L_{ExT/BW}$ (N·m·kg^{-1})	1.9 ± 0.2	2.0 ± 0.2‡	1.9 ± 0.2
$L_{FLEx/ExT}$ (%)	72.7 ± 15.2	66.3 ± 10.9	66.5 ± 11.0
R_{FLEx} (N·m)	105.7 ± 29.5	106.7 ± 22.8	99.1 ± 25.0
$R_{FLEx/BW}$ (N·m·kg^{-1})	1.3 ± 0.3	1.3 ± 0.2	1.2 ± 0.2
R_{ExT} (N·m)	149.8 ± 31.7†	163.3 ± 22.2†	149.5 ± 28.7†
$R_{ExT/BW}$ (N·m·kg^{-1})	1.9 ± 0.3	2.0 ± 0.2	1.9 ± 0.3
$R_{FLEx/ExT}$ (%)	70.2 ± 12.0	65.1 ± 10.2	63.1 ± 11.6
C (*N* = 13)			
L_{FLEx} (N·m)	86.4 ± 14.2	93.9 ± 13.6	88.1 ± 10.5
$L_{FLEx/BW}$ (N·m·kg^{-1})	1.2 ± 0.2	1.3 ± 0.2	1.2 ± 0.2
L_{ExT} (N·m)	125.3 ± 16.2	135.0 ± 14.3	132.2 ± 18.8
$L_{ExT/BW}$ (N·m·kg^{-1})	1.8 ± 0.2	1.9 ± 0.2	1.8 ± 0.2
$L_{FLEx/ExT}$ (%)	70.0 ± 14.2	70.1 ± 10.8	67.3 ± 8.9
R_{FLEx} (N·m)	86.7 ± 19.1	91.9 ± 20.3	85.0 ± 11.0
$R_{FLEx/BW}$ (N·m·kg^{-1})	1.2 ± 0.3	1.3 ± 0.3	1.2 ± 0.2
R_{ExT} (N·m)	124.7 ± 23.6	134.7 ± 21.1	134.0 ± 22.5
$R_{ExT/BW}$ (N·m·kg^{-1})	1.7 ± 0.3	1.9 ± 0.3	1.8 ± 0.3
$R_{FLEx/ExT}$ (%)	71.7 ± 20.7	69.3 ± 16.3	64.6 ± 10.6

*E = experimental group; C = control group; right (R) and left (L) knee flexors and extensors = absolute (L_{FLEx}, L_{ExT}, R_{FLEx}, R_{ExT}) and relative values ($L_{FLEx/BW}$, $L_{ExT/BW}$, $R_{FLEx/BW}$, $R_{ExT/BW}$); hamstring to quadriceps ratio ($L_{FLEx/ExT}$ and $R_{FLEx/ExT}$).
†$p \leq 0.05$ with respect to group C.
‡$p \leq 0.05$ with respect to first measurement.
§$p \leq 0.05$ with respect to second measurement.

Table 5. Changes in mean values (±*SD*) of jump height, maximal power and VISA-P questionnaire in tested groups.*

Test	Measurement	Group: *E* (*N* = 15)	Group: *C* (*N* = 13)
Jump height (cm)	First	40.1 ± 5.0	39.2 ± 5.2
	Second	41.0 ± 3.1	40.4 ± 4.8
	Third	40.8 ± 5.2	39.9 ± 4.4
Maximal power (W)	First	2011 ± 467.5	1968.5 ± 432.7
	Second	2117.9 ± 522.1	1908.2 ± 397.2
	Third	2157.1 ± 579.7	1932.8 ± 406.1
VISA-P questionnaire (points)	First	84.6 ± 13.5	92.3 ± 9.6
	Second	86.4 ± 12.6	90.6 ± 11.1
	Third	90.3 ± 12.2†	94.3 ± 7.2

*E = experimental group; C = control group.
†$p \leq 0.05$ with respect to group C.

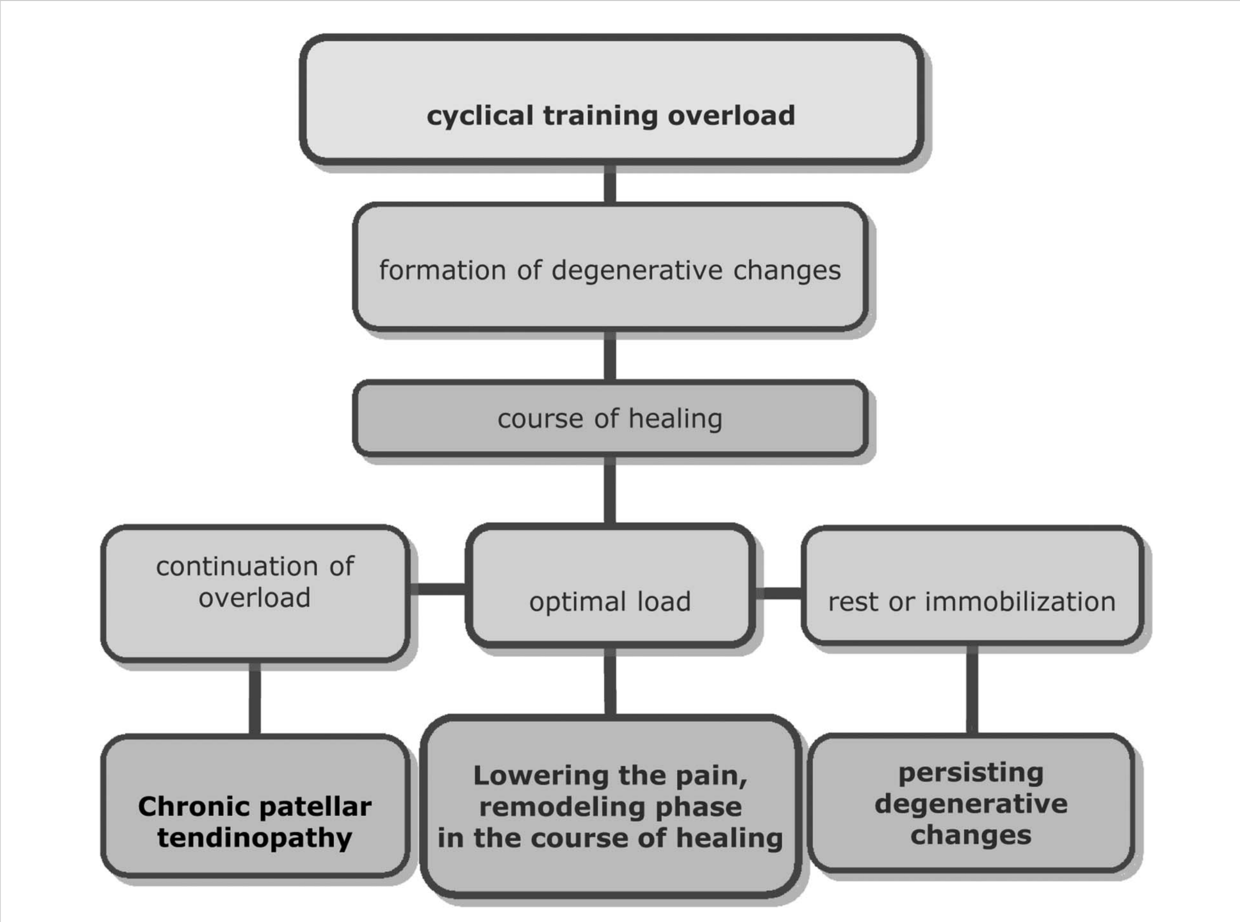

Figure 2. The scheme of genesis factors and treatment of patellar tendinopathy in athletes.

period were not significant in the experimental and control groups. Mean ± *SD* of knee muscle strength peak torques are given in Table 2 (isometric contraction) and Tables 3 and 4 (isokinetic concentric contraction).

Results of jump height, maximal power and VISA-P test are presented in Table 5. The changes measured during the counter-movement jump test (jump height and power) during the period of testing were not significant neither in the experimental nor in the control group.

In reference to the experimental group, it was verified that the average number of points in the VISA-P questionnaire in the third measurement was significantly higher than in the first and second measurements. This means that the level of pain in the experimental group lowered significantly. In the control group, the average number of points in VISA-P questionnaire did not change significantly in the following evaluations.

Discussion

In our tests, the occurrence of patellar tendinopathy among 16- to 19-year old volleyball players was verified, which confirms the results of other authors, e.g., Cook (10). This is not with agreement with Briner and Benjamin (8), which suggested that patellar tendinopathy occurs among athletes only in the third decade of life.

The frequency of occurrence of patellar tendinopathy among tested players, of 18%, is higher than numbers reported by other authors testing young players. For example, Cook (10) found out the occurrence of patellar tendinopathy among 7% of 14- to 18-year old basketball players and Gisslen et al. (24) among 11% of volleyball players below the age of 18.

Similar to Cook (10), this work shows that the number of players with symptoms and morphological changes increases with age. Patellar tendinopathy was diagnosed in 1 player at the age of 16 and in 4 players at the ages between 17 and 19.

It was verified, like in the tests by Konsgaard et al. (35), that morphological changes in the USG image in most cases refer to proximal patellar attachment.

It was confirmed that morphological changes within patellar tendon have no direct connection with pain, but they may indicate higher risk of patellar tendinopathy occurrence. A bigger number of players with morphological changes within patellar tendon (40%) than players with diagnosed patellar tendinopathy confirm the fact. In VISA-P questionnaire, the players with diagnosed patellar tendinopathy gained 63 points on average and it is a similar result to those presented by Visentini et al. (53)–55 points and by Frohm (18)–47 points. In the tests done by Jonsson and Alfredson (28), which engaged players with patellar tendinopathy, comparing the effects of 2 phases, eccentric and concentric, in the squat on decline board, the results showed lowered pain and improvement of functions among players who underwent eccentric training for over 12 weeks. Applied for the same time concentric training did not lower the pain. Also, comparing a squat on decline board to a squat on flat surface, the effects of the first one were more positive. The pain evaluated with VISA-P questionnaire was lower in the group doing eccentric training.

Visnes et al. (54) showed that the application of 12-week rehabilitation protocol during sports season with the squat on decline board in players with patellar tendinopathy did not bring changes of results in VISA-P questionnaire.

In the experiment carried out by Frohm (18), the tested athletes from 1 group did squats on Bromsman device, 4 series of 4 repetitions, every day for 12 weeks with the load on the mass up to 320 kg. The second group did eccentric squat on decline board, 3 series of 15 repetitions, every day for 12 weeks. General overload, in reference to the number of repetitions and average value of power affecting patellar tendon, was 10 times higher in the group doing squats on decline board compared with the group exercising on Bromsman. The results achieved with VISA-P questionnaire after 12 weeks were similar in both groups.

Bahr et al. (5) compared the effect of surgical treatment and applied 12-week rehabilitation protocol with eccentric squat on decline board with the inclination angle of 25° as the key element of the protocol. The injured athletes qualified for surgical treatment and for conservative treatment felt strong pain before and after the training session, so they could not participate in sports sessions with the same intensity, as before the occurrence of symptoms. After 12 months, the results were similar in both groups. The application of intensive 12-week eccentric training is recommended before the decision about surgical treatment (5).

The analyses of test results and observations of players lead to the conclusions that the efficiency of rehabilitation protocol may be higher when the player is excluded from trainings. Alfredson et al. (4) and Fahlstrom et al. (17) as the first documented, the efficiency of 12-week eccentric training in case of Achilles tendinopathy excluding patients from running trainings for about 6–8 weeks. Concerning players with patellar tendinopathy, the application of 12-week program with eccentric squat on decline board before sports season lowered pain evaluated with VISA-P questionnaire (58). A similar effect was achieved in tests carried out by Purdam et al. (46) and Jonsson and Alfredson (28). Also Frohm (18) showed the efficiency of eccentric squat on decline board with simultaneous exclusion of tested athletes from sports training. Yet, considering patients tested by Visnes et al. (54), which applied eccentric squat on decline board along with training, the level of pain did not change.

Regarding both the data from current world literature (10,22,24), and indicated in this work occurrence of patellar tendinopathy among young volleyball players, it was justified to work out a scheme, which can be applied to diagnose pathologies early, e.g., so-called jumper's knee and to use the following treatment. We recommend application of the following scheme.

1. Identifying athletes suffering from pain within knee joint–overwieving their medical history once a year when it concerns groups of young athletes to find those suffering from pain within knee joint.
2. The application of VISA-P questionnaire–at least twice a year, preferably before the preparatory period and during starting period, among players complaining about pain around knee joint to specify if they suffer from patellar tendinopathy.
3. Clinical diagnosis–evaluation of athletes done by an orthopedic surgeon, who diagnosed patellar tendinopathy on the basis of VISA-P questionnaire.
4. The USG test (with color Doppler function)–verification of clinical evaluation, which enables precise location of morphological changes and detecting ingrown neovessels.
5. The measurement of maximal strength, power and jumping and stretching the muscles in the knee joint and around the ankle joint–systematically lead (every 2 months) helping to assess physical capabilities of players, the application of the measurement protocol presented in this work is highly recommended.
6. The education of players–teaching sports people correct and safely done specific, functional exercises, e.g., jumping technique to minimize the value of load affecting patellar tendon, and the explanation of the mechanism and genesis of patellar tendinopathy.
7. The application of the rehabilitation protocol–created and carried out by a physiotherapist, with the use of eccentric squat on decline board and functional exercises, correcting biomechanical disorders.
8. Continuation of eccentric squat on decline board along with functional exercises throughout all training season at least 3 times a week.

Figure 2 represents the schematic description of patomechanism and therapy applied for patellar tendinopathy in athletes.

This copyright scheme underlines that both excessive, cyclic, long-term training overload and complete exclusion of the player from the training process, in a similar way negatively affect patellar tendon. Permanent overload of patellar tendon leads to slow pace of recovery and consequently to impairment of its activity and endangers its tear. Furthermore, lack of stimulating, optimal training stimulus increases degenerative changes, which lowers the strength and resilience of patellar tendon. Excluding players from trainings and then including them into the team most frequently leads to recurrence of symptoms and, thus, we deal with "vicious circle" of increasing degenerative changes.

Correctly lead strength training focused on eccentric exercises, along with correction of biomechanical disorders, gives the athlete a chance to come back to the training process.

Practical Applications

The current study indicates that in 16- to 19-year old volleyball players, 18% suffered patellar tendinopathy. What more it was demonstrated that the number of players suffering that injury increases with age and length of sport career. We found it quite practical to add 24 weeks training program including key eccentric squat on decline board and functional exercises. The implementation of applied protocol was significantly lowered the level of pain in young volleyball players. We also found that 24 weeks of training did not significantly influenced both knee extensors/flexors muscle strength and maximal power and jumping ability of the young players. Thus, the presented rehabilitation protocol applied without interrupting the competitive period allows to overcome jumper's knee with no significant change of muscle strength, maximal power and jumping ability average values of young volleyball players.

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