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Assessing Knee Stability in Adolescent Athletes with Osgood-Schlatter Disease Using the Y-Balance Test

Testování stability kolena u adolescentních sportovců s m. Osgood-Schlatter pomocí Y-Balance testu

V. HLADKY[1], A. KAPLAN[2], J. SMETANOVA[3], V. HAVLAS[1]

[1] Department of Orthopaedics and Traumatology, 2nd Faculty of Medicine, Charles University and Motol University Hospital, Prague, Czech Republic
[2] Department of Track and Field, Faculty of Physical Education and Sport, Charles University Prague, Czech Republic
[3] Department of Rehabilitation and Sports Medicine, 2nd Faculty of Medicine, Charles University and Motol University Hospital, Prague, Czech Republic

ABSTRACT

PURPOSE OF THE STUDY

Osgood-Schlatter disease develops secondary to chronic patellar tendon overloading. The present study was designed to determine whether athletes with Osgood-Schlatter disease perform significantly worse in the Y-Balance Test compared to healthy subjects in a control group.

MATERIAL AND METHODS

The study involved ten boys (average age 13.7 years). Seven participants had bilateral knee pain, swelling and tenderness whereas three had unilateral knee pain, swelling and tenderness (left knee in two cases, and right knee in one). Overall, 17 knees were assessed (left knee in nine cases and right knee in eight). Ten healthy adolescent professional football players (mean age 14.6 years) were selected as a control group. In both groups, complex knee stability was assessed using the Y-Balance Test and their data were analyzed using the methodology developed by Plisky et al. The test outcome was expressed in indexed (normalized) values for the right and left lower extremities, and averaged values for the individual directions were compared.

RESULTS

Significant differences between both groups were shown in the posteromedial and posterolateral directions.

CONCLUSIONS

Using the Y-Balance Test, our study documented reduced performance in the above directions in patients with Osgood-Schlatter disease.

Key words: Osgood-Schlatter disease, knee, balance test, movement patterns patellar tendon overload.

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INTRODUCTION

In this paper, we focus on adolescent patients with Osgood-Schlatter disease (OSD hereinafter) (14, 17), a condition usually diagnosed in pediatric patients, affecting as it is the immature skeleton. However, the relationship between bone maturity and the actual pathogenic mechanism, remains unclear (11). Osgood-Schlatter disease, previously categorized among aseptic necroses, is today known as traction apophysitis of the tibial tubercle (20). Patellar tendon traction leads to partial microavulsions of the cartilaginous and, subsequently, osseous tuberosity (6, 11, 21). Since girls reach osseous maturity on average 1–2 years earlier than boys, the disease in girls is mostly diagnosed at the age of 8–14 years and, in boys, at the age of 10–15 years (12, 16).

The relevant literature agrees that OSD is an overuse syndrome of the pediatric knee (22). The patellar tendon is stressed by the action of forces in the absolute sense.

We believe that overuse may also be relative, and may be caused by incorrect or non-physiological movement patterns. It means that overloading may also occur in cases when the force with an effect on the ligament is equivalent to the ordinary load. Importantly, the effective forces increase if combined with a non-physiological movement pattern. In our study, complex knee stability was assessed using the Y-Balance Test (YBT hereinafter). Having assumed a relationship between the development of the disease and movement patterns, it is advisable to

Table 1. OSD group data – obtained during first session

Participant No.	Sport	Weight (kg)	Height (cm)	BMI
1	football	55	160	21.48
2	rugby gymnastics	52	153	22.21
3	rugby	68	185	19.87
4	ball hockey	85	186	24.57
5	floorball swimming	72	179	22.47
6	floorball	72	185	21.04
7	handball	52	172	17.58
8	football	52	155	21.64
9	football	50	168	17.72
10	hockey	68	158	27.24

Table 2. Control group data – football players

Participant No.	Position	Dominant foot	Height (cm)	Weight (kg)	BMI
11	midfielder	left	175	65	21.22
12	midfielder	right	178	67	21.15
13	midfielder	right	173	60	20.05
14	defender	right	182	68	20.53
15	defender	right	158	50	20.03
16	defender	right	167	64	22.95
17	defender	right	179	65	20.29
18	forward	right	156	47	19.31
19	forward	right	183	77	22.99
20	midfielder	right	178	63	19.88

carry out not only effective screening but, also, subsequent movement analysis in order to identify incorrect movement patterns. These can then be eliminated by individual rehabilitation (13, 16).

The goal of this study was to determine whether adolescent athletes with OSD perform significantly worse in all or some YBT directions compared to a control group, i.e. whether some association with OSD could exist.

MATERIAL AND METHODS

Participants

The study group included 10 boys with OSD with a mean age of 13.7 (12–16) years. Seven participants had bilateral knee pain, swelling and tenderness, whereas, three reported unilateral knee pain (left knee in two cases, and right knee in one). Overall, 17 knees were assessed (left knee in nine cases and right knee in eight).

These were amateur athletes (2–3 regular organized training sessions per week) without any musculoskeletal or nervous system dysfunction except for the above OSD diagnosis (Table 1).

As a control group, ten healthy adolescent professional soccer players were selected (mean age 14.6 years), see Table 2. Before testing, all subjects and their parents gave their informed consent to participate in the study. The local ethics committee consent was obtained to perform this study.

Figure 1. YBT testing is performed in the anterior direction.

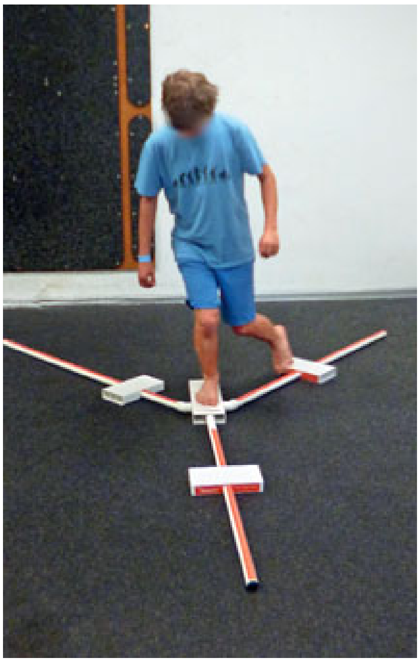

Figure 2. YBT testing is performed in the posteromedial direction.

Figure 3. YBT testing is performed in the posterolateral direction.

Procedures

All study participants had both their lower extremities assessed using the YBT. Patients with OSD had only knees with the above diagnosis assessed and statistically analyzed (i.e., 17 knees). To obtain the highest number of values for the left and right lower extremities, measurements in the OSD group were performed three times at an interval of 5–6 months. In our view, both dominant and non-dominant extremities had to be assessed for our comparison; hence both extremities were compared separately. However, we assumed that the proportions of lower extremity dominance were similar in both groups.

The control group had only one YBT measurement to obtain reference data from healthy individuals represented by professional athletes.

The Functional Movement Screen (FMS) YBT protocol as proposed by Plisky et al. (15) was used in both groups. The YBT is performed in three directions, anterior (ANT) (Fig. 1), posteromedial (PM) (Fig. 2) and posterolateral (PL) (Fig. 3). Viewed from the above, these directions resemble an upturned letter "Y".

During the YBT, the examined patient stands on one lower extremity (LE) (the so-called single leg stance) using the other leg to consecutively shift movable blocks in the above three directions (ANT, PM, PL). The measurements for each LE are repeated to achieve three correct attempts. The movement performance was documented by video recording. The collected data represent values achieved in a given direction (in cm). These were recorded and further analyzed according to the original methodology of Plisky et al. (15).

The test outcome is expressed in indexed (normalized or re-calculated) values for the right and left lower extremities (RLE and LLE hereinafter). It is normalized to limb length and expressed as a percentage. In this way, values are obtained for each direction and can be subsequently averaged into one "composite" value for the given LE. The indexed value is calculated as follows: the maximum distance reached is selected from three correctly performed attempts for the given direction (in cm), and divided by the length of the LE (working limb length – WLL hereinafter, in cm), which, according to the methodology proposed by Plisky et al. (15) is determined by the distance from the *spina iliaca anterior superior* (SIAS) to the tip of the medial malleolus (in cm). On the basis of this re-calculation, results can be compared irrespective of the body height of the patients. For the calculation formulae, see Table 3.

The YBT measurements for the control group of professional adolescent football players were performed in the same fashion with only one repetition of the test.

Statistical analysis

The individual indexed values for each direction (ANT, PM, PL) and extremity (LLE, RLE) were averaged to be further analyzed, always comparing the same directions and the same extremities between the groups. We conducted a hypothesis test to see whether or not there was a significant difference between the two groups (i.e., OSD group and control group) assuming equal variances. The data were tested using a two-sample t-test assuming equal variances. The level of significance was set at $p \leq 0.05$, and all hypotheses were two-tailed. All statistical analyses were performed using Microsoft Excel (Microsoft Corporation, Redmond, WA, USA).

Table 3. Calculation of indexed values

Indexed (normalized) values	(ANT_{MAX} or PM_{MAX} or PL_{MAX}) x x 100 : working limb length
Composite indexed values	(ANT_{MAX} or PM_{MAX} or PL_{MAX}) x x 100 : 3 x working limb length
Indexed values are expressed as a percentage Directions (axes): ANT – anterior, PM – posteromedial, PL – posterolateral MAX – the maximum value achieved for given direction Workng limb lenght (WLL) = distance from SIAS to the tip of the medial malleolus (in cm)	

RESULTS

The baseline data for the OSD group obtained in separate measurements are shown in Tables 4a and 4b, the control group data are presented in Tables 5a and 5b.

Left lower extremity

The values obtained for the left lower extremity are shown (as normalized and indexed values, respectively) in Table 6a. The average values for the anterior (ANT) direction in the OSD and control groups were 62,584 and 68,917, respectively ($p = 0.047$). The average values for the posteromedial (PM) direction in the OSD and control groups were 102,796 and 111,552, respectively ($p = 0.013$). The average values for the posterolateral (PL) direction in the OSD and control groups were 99,384 and 112,141, respectively ($p = 0.0002$).

To sum up the above results, there was a significant difference for the left lower extremity in all three directions between both groups, with the difference being the most and least significant for the PL and ANT directions, respectively.

Right lower extremity

The values obtained for the right lower extremity are shown in Table 6b. The average values for the anterior (ANT) direction in the OSD and control groups were 61,015 and 63,994, respectively ($p = 0.168$). The average values for the posteromedial (PM) direction in the OSD and control groups were 102,065 and 121,426, respectively ($p = 0.000007$). The average values for the posterolateral (PL) direction in the OSD and control groups were 101,38 and 117,55, respectively ($p = 0.0006$).

Analysis of our results for the right lower extremity showed significant differences in the PM and PL directions. The differences between the groups were the most and less significant for the PM and PL directions respectively. No significant difference was noted in the anterior (ANT) direction.

Table 4a. Data processed for LLE according to the Plisky et al. methodology

YBT-LQ		Affected knee	LLE lenght	LLE							
				ANT max.	PM max.	PL max.	Max. LLE summed	Ind. ANT	Ind. PM	Ind. PL	LLE composite
1. meas.	Proband 1	Left,	83	52.5	80.5	78	211	63.25	96.99	93.98	84.74
2.			87	55	81.5	81.5	218	63.22	93.68	93.68	83.52
3.			91	59.5	92	90	241.5	65.38	101.1	98.9	88.46
1. meas.	Proband 2	Right	86	60.5	98	106	264.5	70.35	113.95	123.26	102.52
2.			90	55.5	102	98	255.5	61.67	113.33	108.89	94.63
3.			91	56.5	102	104.5	263	62.09	112.09	114.84	96.34
1. meas.	Proband 3	Bilateral	101	57.5	100.5	94	252	56.93	99.5	93.07	83.17
2.			103	59.5	113.5	104.5	277.5	57.77	110.19	101.46	89.81
3.			104	63	111.5	96	270.5	60.58	107.21	92.31	86.7
1. meas.	Proband 4	Bilateral	99	62	99	99	260	62.63	100	100	87.54
2.			100	60	99	101	260	60	99	101	86.67
3.			100	52	95	106	253	52	95	106	84.33
1. meas.	Proband 5	Bilateral	92	58	106.5	87.5	252	63.04	115.76	95.11	91.3
2.			94	52.5	94	92	238.5	55.85	100	97.87	84.57
3.			96	57.0	89.5	85	231.5	59.38	93.23	88.54	80.38
1. meas.	Proband 6	Bilateral	99	66	110	104	280	66.67	111.11	105.05	94.28
2.			100	68.5	109	107.5	285	68.5	109	107.5	95
3.			101	63.5	107.5	98	269	62.87	106.44	97.03	88.78
1. meas.	Proband 7	Left	93	65	99	97.5	261.5	69.89	106.45	104.84	93.73
2.			95	67	105	98.5	270.5	70.53	110.53	103.68	94.91
3.			99	59	112.5	110.5	282	59.6	113.64	111.62	94.95
1. meas	Proband 8	Bilateral	83	54	82	76.5	212.5	65.06	98.8	92.17	85.34
2.			85	61	91	88.5	240.5	71.76	107.06	104.12	94.31
3.			88	58	92	91	241	65.91	104.55	103.41	91.29
1. meas	Proband 9	Bilateral	87	47.5	81	85	213.5	54.60	93.1	97.7	81.8
2.			87	55	76.5	79.5	211	63.22	87.93	91.38	80.84
3.			87	58	83	88	229	65.91	94.32	100	86.74
1. meas	Proband 10	Bilateral	83	49.5	89.5	81.5	220.5	59.64	107.83	98.19	88.55
2.			83	52	90	85	227	61.9	107.14	101.19	90.08
3.			84	53.5	89	87	229.5	63.69	105.95	103.57	91.07

LLE, RLE – left and right lower extremity
Meas. – measurement

Comparison of the right and left lower extremities

While there was a significant difference in all three directions for the LLE, no such trend was seen for the RLE as the difference was not significant in the anterior (ANT) direction, which is why we believe the left and right lower extremities should be assessed separately instead of analyzing composite data for the left and right lower extremities.

DISCUSSION

The constantly growing demands on child athletes' performance lead to increasing numbers of pediatric patients with musculoskeletal disorders, a fact which makes us believe that early identification of patients at risk of OSD development, as well as their properly tailored treatment, would certainly be of benefit, particularly in cases of elite athletes in junior categories.

Table 4b. Data processed for RLE according to the Plisky et al. methodology

YBT-LQ		Affected knee	RLE lenght	RLE							
				ANT max.	PM max.	PL max.	Max. RLE summed	Ind. ANT	Ind. PM	Ind. PL	RLE composite
1. meas.	Proband 1	Left	83	59.5	82	74	215.5	71.69	98.8	89.16	86.55
2.			87	61	95	84	240	70.11	109.2	96.55	91.95
3.			91	59.5	90	93.5	243	65.38	98.9	102.75	89.01
1. meas.	Proband 2	Right	86	56	88	87	231	65.12	102.33	101.16	89.53
2.			90	54.5	92.5	102	249	60.56	102.78	113.33	92.22
3.			91	58	103	105	266	63.74	113.19	115.38	97.44
1. meas.	Proband 3	Bilateral	101	53.5	96.5	102	252	52.97	95.54	100.99	83.17
2.			103	55.5	102	100	257.5	53.88	99.03	97.09	83.33
3.			104	55.5	107.5	103	266	53.37	103.37	99.04	85.26
1. meas.	Proband 4	Bilateral	100	58	94	88	240	58	94	88	80
2.			100	53	87	90	230	53	87	90	76.67
3.			100	51	83.5	84.5	219	51	83.5	84.5	73
1. meas.	Proband 5	Bilateral	92	56	98.5	97	251.5	60.87	107.07	105.43	91.12
2.			94	55	98	95	248	58.51	104.26	101.06	87.94
3.			96	58.5	98	95.5	252	60.94	102.08	99.48	87.5
1. meas.	Proband 6	Bilateral	99	64	109	110	283	64.65	110.1	111.11	95.29
2.			100	68	114	108	290	68	114	108	96.67
3.			101	64	107	104	275	63.37	105.94	102.97	90.76
1. meas.	Proband 7	Left	93	67	102.5	105	274.5	72.04	110.22	112.9	98.39
2.			95	61.5	106	108.5	276	64.74	111.58	114.21	96.84
3.			99	61	111	108	280	61.62	112.12	109.09	94.28
1. meas.	Proband 8	Bilateral	83	54.5	87	87.5	229	65.66	104.82	105.42	91.97
2.			85	58	92.5	90	240.5	68.24	108.82	105.88	94.31
3.			88	60	95	93	248	68.18	107.95	105.68	93.94
1. meas	Proband 9	Bilateral	87	54	85	80.5	219.5	62.07	97.7	92.53	84.1
2.			87	63.5	85	87.5	236	72.99	97.7	100.57	90.42
3.			88	57	87	91	235	64.77	98.86	103.41	89.02
1. meas	Proband 10	Bilateral	83	47	84	79	210	56.63	101.2	95.18	84.34
2.			84	50	88	85	223	59.52	104.76	101.19	88.49
3.			84	49	87	88.8	224.8	58.33	103.57	105.71	89.21

LLE, RLE – left and right lower extremity
Meas. – measurement

Our study was based on the assumption that overuse of the patellar tendon attachment can be both absolute and relative. In their study, Kaneuchi et al. (11) did not observe a correlation between development of the disease and the length of time the patient had been exposed to the physical load (the so-called "total practice time") a finding which, to a certain extent, refutes the idea of overuse syndrome. By contrast, Blankstein et al. (1) claimed that the risk group includes adolescent patients who are active athletes. The movement activities that strain the ligament to a greater or lesser extent have been described (10, 12, 16).

Our hypothesis of relative patellar tendon overload in Osgood-Schlatter disease was actually developed as an analogy to patients sustaining injury to the anterior cruciate ligament (ACL hereinafter) where the so-called dynamic knee valgus acts as a significant risk factor (8, 19). It is an incorrect movement pattern that increases the risk of traumatic rupture (9, 13, 19). The risk can be estimated by targeted examination of movements. Mehl et al. suggested that a proper training program targeted at correct movement performance can reduce the risk of knee injury by as much as 27% and, in the case of ACL, by as much as 51% (13).

Table 5a. Control group – data processed for LLE

Participant No.	LLE lenght	LLE							
		ANT max.	PM max.	PL max.	Max. LLE summed	Ind. ANT	Ind. PM	Ind. PL	LLE composite
11	89	56.5	97	96	249.5	63.48	108.99	107.87	93.45
12	85	88	123	122	333	103.53	144.71	143.53	130.59
13	90	58	98	101	257	64.44	108.89	112.22	95.19
14	96	52.5	98.5	97	149.5	54.69	102.60	101.04	86.11
15	83	61	96	103	260	73.49	115.66	124.10	104.42
16	84	50	95	90	235	59.52	113.10	107.14	93.25
17	93	64	93	108	265	68.82	100.00	116.13	94.98
18	92	68	93	92	253	73.91	101.09	100.00	91.67
19	96	52	110.5	105	267.5	54.17	115.10	109.38	92.88
20	93	68	98	93	259	73.12	105.38	100.00	92.83

LLE. RLE – left and right lower extremity

Table 5b. Control group – data processed for RLE

Participant No.	RLE lenght	RLE							
		ANT max.	PM max.	PL max.	Max. LLE summed	Ind. ANT	Ind. PM	Ind. PL	RLE composite
11	89	55	95	78.5	228.5	61.80	106.74	88.20	85.58
12	85	62	126	133	321	72.94	148.24	156.47	125.88
13	90	60	102	103	265	66.67	113.33	114.44	98.15
14	96	59	109.5	104	272.5	61.46	114.06	108.33	94.62
15	83	58	110	103	271	69.88	132.53	124.10	108.83
16	84	50	92	103	245	59.52	109.52	122.62	97.22
17	93	53	100	97	250	56.99	107.53	104.30	89.61
18	92	57	113	104	274	61.96	122.83	113.04	99.27
19	96	57.5	118	114.5	290	59.90	122.92	119.27	100.69
20	93	64	127	116	307	68.82	136.56	124.73	110.04

LLE, RLE – left and right lower extremity
ANT, PM, PL – anterior, posteromedial, posterolateral direction

Our study participants were assessed using the Y-Balance Test developed by Phillip Plisky based on the concept of Gray Cook, the author of “Functional Movement Systems” (3–5). YBT is one of four subsystems used for the measurements and assessment of kinesiological patterns; the other three are FMS™ – Functional Movement Screen, SFMA™ – Selective Functional Assessment and FCS™ – Functional Capacity Screening (3).

In routine practice, the YBT is used, among other things, to predict the risk of musculoskeletal injury to the lower extremities (13). It shows good to excellent reliability with standardized equipment and methods to examine movement deficits and asymmetries in individuals (15). The indexation or standardization of values serves for comparison of the results obtained regardless of the subject’s body height.

In our view, the YBT is a convenient tool to assess movement skills and to serve as an effective screening tool and, when combined with movement video analysis, it is helpful in clear identification of non-physiological movement patterns.

Authors are aware that the number of patients is relatively small, however, comparative studies (2, 7, 18) involve also relatively small number of patients (i.e. Sipe et al. 30 pts, Gabriel et al. 24 pts, Chimera et al. 20 pts). Therefore we believe that the outcomes received in our study are comparative to those in the literature.

Our study has shown that YBT use demonstrated significantly reduced performance in the posteromedial (PM) and posterolateral (PL) directions in study participants compared to the healthy control group, regardless of the side assessed, i.e., extremity dominance. This does not apply to assessment in the anterior direction (ANT) where a significant difference was noted only in the LLE. The question is whether or not a role is played in this case by the extremity dominance. Likewise, one

Tab. 6a. Statistical analysis for the left lower extremity

t-Test: two-sample assuming equal variances						
LLE	ANT direction		PM direction		PL direction	
	OSD	*Control*	*OSD*	*Control*	*OSD*	*Control*
Mean	62.584	68.917	102.796	111.552	99.384	112.141
Variance	23.334	202.152	51.731	167.344	31.643	179.236
Observations	27.000	10.000	27.000	10.000	27.000	10.000
Pooled variance	69.315		81.460		69.596	
Hypothesized mean difference	0.000		0.000		0.000	
df	35.000		35.000		35.000	
t Stat	–2.055		–2.621		–4.131	
P(T<=t) one-tail	0.024		0.006		0.000	
t Criticalone-tail	1.690		1.690		1.690	
P(T<=t) two-tail	0.047		0.013		0.0002	
t Criticaltwo-tail	2.030		2.030		2.030	

LLE, RLE - left and right lower extremity
ANT, PM, PL – anterior, posteromedial, posterolateral direction
OSD – Osgood-Schlatter disease

Tab. 6b. Statistical analysis of data for the right lower extremity

t-Test: two-sample assuming equal variances						
RLE	ANT direction		PM direction		PL direction	
	OSD	*Control*	*OSD*	*Control*	*OSD*	*Control*
Mean	61.015	63.994	102.065	121.426	101.380	117.550
Variance	32.976	27.370	52.734	193.985	57.081	309.988
Observations	24.000	10.000	24.000	10.000	24.000	10.000
Pooled variance	31.399		92.461		128.211	
Hypothesized mean difference	0.0000		0.000		0.000	
df	32.000		32.000		32.000	
t Stat	–1.412		–5.349		–3.794	
P(T<=t) one-tail	0.084		0.000003594		0.0003	
t Criticalone-tail	1.694		1.694		1.694	
P(T<=t) two-tail	0.168		0.000007		0.0006	
t Criticaltwo-tail	2.037		2.037		2.037	

LLE, RLE – left and right lower extremity
ANT, PM, PL – anterior, posteromedial, posterolateral direction
OSD – Osgood-Schlatter disease

should ask whether or not the level of performance is reduced by the disease per se or non-physiological movement patterns. However, it should be noted that excluded from the study were all individuals showing any signs of pain during measurement as this would have naturally biased the data.

CONCLUSIONS

The main goal of the study was to receive a comparative numbers of the cohort of OSD patient versus the healthy control group. Using instrumental measurements, we were able to demonstrate significant differences between the two groups in the posteromedial and posterolateral directions suggesting that an association between OSD and reduced performance can be confirmed by the YBT.

Using the Y-Balance Test, our study documented significant differences between both groups in the posteromedial and posterolateral directions in patients with Osgood-Schlatter disease.

Ethics approval

The study was conducted according to the guidelines of the Declaration of Helsinki, publication of the outcome data was approved by the local Ethics Committee of University Hospital Motol and 2nd Faculty of Medicine, Charles University in Prague (protocol code EK-1121/21, approved on 23 Aug, 2021).

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Corresponding autor:
Vit Hladky,
Department of Orthopaedics and Traumatology
2nd Faculty of Medicine
Charles University and Motol University Hospital
V Úvalu 84
Prague, Czech Republic
E-mail: vit.hladky@gmail.com