EVALUATION OF THE CONDITION OF HIGH JUMPERS' LOCOMOTOR SYSTEM IN THE PREVENTION OF HEALTH PROBLEMS

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Abstract:

The ability to resist a high level of physical strain is very demanding for the *condition and function of the support-locomotor system* and is a prerequisite for successful coping with the complex locomotor structure of the event and sports training demands. The current condition of first-rate high jumpers' (N=47) locomotor system has been investigated using a questionnaire and information gathered in controlled interviews with contestants, coaches and sports physicians. Based on the occurrence of jumpers' locomotor system injuries the obtained data have been divided into seven parts (foot, shank, knee, thigh, pelvis, trunk and other) and evaluated statistically. Based on the findings, most male and female jumpers' locomotor system injuries were caused by one or a combination of two and more factors, e.g. high values of forces in the course of take-off, a great number of jumps in conjunction with an inappropriate fitness training, wrong technique or anatomical disposition to injuries. The take-off leg, Achilles tendon, take-off leg knee, pelvis and the lumbar part of the spinal column can be considered to be the critical parts of the locomotor system of high jumpers.

Key words: *high jump, ability, condition and function, locomotor system, training, critical parts, questionnaire, injury statistics*

Introduction

The prerequisite of successful coping with the complicated kinetic structure of the high jump is the ability to resist a high level of physical strain that puts, among others, heavy demands on the condition and function of the athlete's locomotor system. Nowadays, the take-off in athletic events leads up to an explosive execution – a short and strong contact with the ground (t_c = .15–.22 s) reduces the bending of the take-off leg knee. The knee joint is stressed less with this technique, but the damage to other participating parts of the locomotor system increases (Vařeka & Vařeková, 1995; Langer, 2003).

After a more than twenty-year observation of domestic, as well as foreign high jumpers, it can be said that most of the injuries appear unexpectedly, without warning, and the injuries are not characterised by a significant pain that usually relates to serious damage. These "rather strange" injuries are the subject matter of this study.

It is particularly the lower limbs (hereinafter LL) that belong to the anatomically endangered parts of unbalanced body areas. The high jump is a classical example of an unbalanced sports event because of the precise role of each LL during the run-up and take-off, but also because of the inclination of the body during the run to the curve and rotations. The contraction of dual-joint knee flexor muscles on the backside of the femur belongs to the most frequent diagnoses. No less frequent contraction of the sura triceps limits the movement in the ankle joint. Riegerová (1997) and Vařeková & Vařeka (2005) consider that overstrain or chronic overloading above the level given by the quality of a muscle and the asymmetric loading without sufficient compensation to be the main causes of the occurrence of muscular imbalance. The psychological component influencing the locomotor system also has a share in the increase of the muscle tonus.

The morphology of a leg affects the state and functionality of the postural muscles on the LL or it may also exert an influence on the state of the muscle groups and joints in the lower part of the trunk. Přidalová (2002) states that the LL are the limiting factor for the achievement of maximum sports performance. The overload of a leg has an effect on the overloading of the other LL joints as well.

With high jumpers differences in the anatomical structure of the LL are often found, which, when ignored, may cause later complications for athletes

beginning their sporting career. With regard to the large volume and intensity of the load and consequently great absorbed strain often distributed unequally, initial inattention may result in permanent injuries (Langer, 2004, 2005).

It is probable that, with repeatedly exceeding an individual threshold of load intensity, the effect on the locomotor system disappears and sports training may threaten the normal development of the locomotor system in a growing organism. The riskiest age is the early puberty phase (about 14 years of age with girls and 15 years of age with boys), which is characterized by the acceleration of bone growth and the late development of muscles (Máček & Máčková, 2000; Vařeková & Vařeka, 2005).

The basis of improving performance, how to prevent the risk to health and not rely on the cure of the consequences of low fitness level is the improvement of the fitness level through high-quality fitness training. It is advisable to test the effect of jumping on, e.g., a dynamometer-type measuring plate where it is possible to recognize an improper technical performance of the take-off or the symptoms of fatigue – either a long or, conversely, a short time of contact with the ground when taking off, an analysis of the variation of forces in the take-off (absorption as well as active) phase, the co-ordination of body segments, the timing of movements, the unbalanced force parameters, the velocity and acceleration in the course of the take-off, etc. (Langer, 1989; Janura et al., 2002).

Methods

The aim of this paper is to find out and analyse the health problems of a top-level high jumpers' locomotor system which were caused by their intensive sports activities.

The occurrence of injuries and pain in some parts of the locomotor system constantly increase not only in adults, but also in young male and female high jumpers. Injuries of the locomotor system that occur with the high jump in a group of high jumpers in the age group from 16 to 28 have been monitored. The incidence of the occurrence of health problems related to the competitive and top-level sports in 47 responding high jumpers (N_{males} = 29; $N_{females}$ = 18) was high.

A questionnaire was used in order to find out the relevant state of the locomotor system. The monitored athletes recorded a problem and injured body parts briefly in the questionnaire. The method was selected to verify and complete the information obtained through more invasive techniques (*In-Depth Interview and Focus Group Discussion*).

Based on the occurrence of injuries on the high jumpers' locomotor system the obtained data were divided into the seven parts of the body (foot, shank, knee, femur, pelvic girdle, spine, other) and processed using computer technology.

Results

The health problems were found to be located mostly on the take-off leg, in the lumbar and thoracic parts of the spine, in the knee joint of the take-off leg and in the area of the Achilles tendon. The effect of the progressive method of getting over the bar on the health conditions of the high jumpers' locomotor systems was assessed.

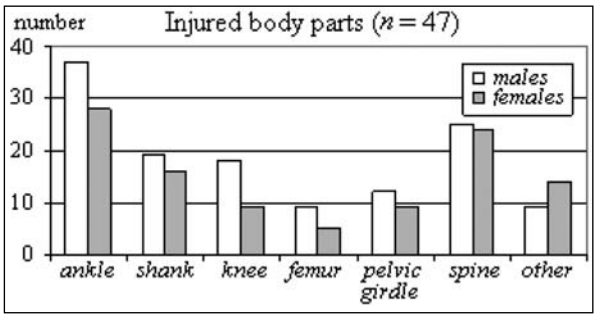

Figure 1. The most frequently injured parts of the body with the top male and female high jumpers in the monitored sets from 1983 to 2005.

Foot

Based on the research it has been discovered that most injuries with younger male and female high jumpers were caused by the following activities:

- the activities that caused ankle eversion or excessive dorsal flexion movement (N_{males} = 18; $N_{females}$ = 15), running aside up a steep slope/stairs – running on the outer side or inner side of ankles (N_{males} = 12; $N_{females}$ = 12),
- frequent walk, run or skips on tiptoes, especially with an excess load, or walk/run in high-heel footwear (N_{males} = 9; $N_{females}$ = 6); fatigue fracture of the 2nd metatarsus centre part (N_{males} = 1; $N_{females}$ = 1),
- extreme stretching of the Achilles tendon and exaggerated strengthening of the sole flexors (N_{males} = 9; $N_{females}$ = 5). Repeated minor injuries of tendons were the causes of damage, especially on landing or on sharp impact on the ground, at a change of direction and at acceleration – most often in the course of the last but one step (non-take-off leg) or at the take-off,
- isometric exercises with a large load when the support under the front part of the sole was heightened (N_{males} = 1; $N_{females}$ = 2),
- insufficient/exaggerated pronation of the sole arising from the unbalanced part of the LL (N_{males} = 3; $N_{females}$ = 3). The effect was a loss of control over the posture of the pelvis, its lateral lowering and in consequence a great lowering of the support leg.

Shank

It has been proven that a large volume and a large frequency of jump take-offs, i.e. the overload at training or racing activities results in acute injury to this part of the LL. Various take-off materials, improper sports footgear, incorrect timing of movements during the run as well as the jump, a long period of contact with the ground during the take-off, significant lowering of the entire centre of gravity, namely in the absorption phase, were the main sources of health problems in female and male high jumpers.

As for the set of high jumpers, frequent types of injuries in the area of the shank were as follows:

- inflammation of the hypodermic fascia of muscle middle insertions on the front part of the shank - periostitis (N_{males} = 15; $N_{females}$ = 11),
- injured calf muscle (N_{males} = 4; $N_{females}$ = 2), and
- overuse fracture of the calf bone in its upper third ($N_{females}$ = 1).

Before taking up an important take-off position, the high jumpers were taking a run-up along the curve very fast ($\bar{v}_x = 8.58\ ms^{-1}$). In this way, the strain caused by the centrifugal force was increasing in the curve. Furthermore, the centrifugal force augmented the requirements for the support leg and its work for the stability of individual limbs – in particular, the outer leg was loaded more.

Knee

As for the examined male and female high jumpers, long-term repeated thrusts were the cause of knee joint injuries. No isolated take-off gave rise to the health problems as follows:

- Acute inflammation of bursae in the area above or below the kneecap as well as a chronic strained knee (N_{males} = 8; $N_{females}$ = 3). In the set of athletes this injury is typical for male and female straddle high jumpers. Three cases of chronic inflammation ended with surgical intervention.
- Kneecap tendinitis – an impairment caused by a too intensive load (N_{males} = 2; $N_{females}$ = 1). The tendon between the kneecap and the front part of the shank is stressed by strong pressure in the course of the knee extension, especially in the course of an intensive run, but mainly with take-offs and jumping. Problems with directional stability often occur.
- Injuries during fitness activities – mainly repeated half knee bends and knee bends, often with a heavy load (N_{males} = 7; $N_{females}$ = 2). When strengthening the muscles of the LL, high jumpers will not probably avoid half knee bends, during which time the patella-femoral joint may be loaded up to 7 times its body weight (Chaloupka & Nýdrle, 2001).

  Note: Knee bends that cause serious knee joint damage according to Anderson, Courtney, and Carmeli (1998) are often included in the training of high jumpers. The same author investigated the muscular activity of the quadriceps during dynamic knee bends. It has been proven that the greatest stress was in the lower part of the quadriceps. Knee bends and primarily half knee bends are very controversial kinetic elements evoking discussions among athletes and trainers as well as physicians and physiotherapists.

It is presumed that knee bends, even if performed technically correctly, will bring more problems than benefits in athletes who are just beginning. In most cases patella-femoral difficulties increase with flexion – the larger the flexion in the knee joint, the larger the pressure that affects the lower side of the kneecap.

Femur

When the LL of high jumpers are evaluated, a high fitness level and a large muscular force of the quadriceps or gluteal muscles are obvious. On the other hand, the rear parts of the femur do not often fulfil the basic parameters for the high jump. After a large number of jumps and a high load of intensity there are many hamstring muscles injuries:

- constraints, interruptions or a total stop in the gradual improvement of performance (N_{males} = 9; $N_{females}$ = 5).

Pelvic girdle

Even if pain in this area occurs more often with football players and runners, it affects high jumpers as well. A chronic lingering pain, due to its stubborn unpleasant character, brings about problems and origination of pathology in the area of the muscular girdle of the pubic bone – pubalgy - from the very beginning.

Pain in the area of the pubic bone usually appears in the course of heavy training as well as during racing load:

- heavy load and insufficient rest, too intensive training after a long pause, misdirected strengthening, insufficient warm-up or no warm-up (N_{males} = 2; $N_{females}$ = 1),
- bad terrain, uphill/upstairs running, uneven ground and improper footgear are the biomechanic factors of the locomotor chain resulting from the bodily structure (N_{males} = 8; $N_{females}$ = 5),
- excessive stress (hypotony) of the abdominal wall, excessive stress in the area of the groin and inguinal canal in the Fosbury flop technique (N_{males} = 10; $N_{females}$ = 9).

Spine

With high jumpers there were usually functional failures of static and dynamic related to the overload of the spinal discs and ligaments caused by the muscular imbalance. A certain genetic disposition to the build-up of a loose ligament is presumably a participating factor of these injuries. The high jump showed itself to be an aetipathogenetic factor, especially in activities related to the vertical overloading of muscles, rotations and extreme lateral inclinations of the vertebrae. In these cases there were the following injuries:

- injuries to discs caused by repeated overload ($N_{males} = 15$; $N_{females} = 11$),
- momentary disc slippage outside of the intervertebral area ($N_{males} = 13$; $N_{females} = 11$),
- the spondylolisthesis (the shift of the last lumbar vertebra against the sacral bone forward as a consequence of the action of mechanical tensions and pressures in the area of the weakened intervertebral ligaments and muscles); ($N_{males} = 7$; $N_{females} = 10$).

Discussion and conclusion

Based on the evaluated protocols of the guided interviews with top-level athletes and in consideration of the measured values of forces acting in the high jump it ensues uniquely that most injuries of the locomotor system are caused by one or a combination of two or more of the following factors:

- high values of reaction forces at the take-off,
- inadequate training load,
- unbalanced fitness training (especially with the high jumpers who are beginners),
- imperfect technique of the take-off,
- anatomical disposition to injuries.

High value of reaction forces

The values of reaction forces augmented by the technique, artificial surfaces and special sports footgear are high. A strain is imposed particularly on joints, ligaments, tendons, muscles or fasciae and bones that must outlast the stress in the course of the heavy load activities in jumps.

In the high jump the LL are burdened with a time variable force that results from contact with the ground (the influence of weight and inertial forces) and from the action of muscles.

The abductors of the hips are called upon to stabilise the pelvis against the excessive lateral thrust that originates from the support on one leg. This happens not only in the take-offs, but also in bodybuilding using heavy dumb-bells and in plyometric exercises.

The take-off leg often takes over the dominant position and the other (swing leg) causes the opposite hip or, if needed, the hip together with the pelvis, to lower.

Inadequate training load

The athlete makes efforts to achieve higher performances, which means a constant increase of the training stress. In this way the volume[1] and particularly, with advanced high jumpers, the intensity of the demanding kinetic activities increases (Langer, 2004).

Unbalanced fitness training

A novice high jumper, especially a gifted high jumper, who improves very quickly, is exposed to the enhanced risk of injury. The physical condition of gifted beginners is often low and its improvement is often unbalanced because of the high frequency.

At the other extreme, experienced high jumpers have specific parts of their bodies that are prone to injuries and augment harmful influence or vice versa; certain parts of their bodies are prone to injuries far less than the other parts of their bodies.

It is assumed that the only alternative and the only possibility of preventing injuries or improving performance constantly is to enhance the overall fitness level.

Imperfect take-off technique

The primary element of the take-off is to step on the forepart of the sole of the take-off leg quickly. Therefore, during the studies, the demanding technique of placing the sole on the ground in the absorption phase (amortization) was followed closely and the total time of contact of the foot with the ground was analysed in detail.

The talented beginner high jumpers consider the high jump to be a natural activity. The augmented volume of repetitions will show that the take-off leg is the main part of the demanding dynamic explosive kinetic activity.

Anatomical predisposition to injuries

Following the take-off, top-level high jumpers have a specific anatomical structure, often power unbalanced. Some parts of their bodies are less supple, flexible and elastic – all of which leads to a predisposition to injuries.

In general, differently balanced parts of the LL, e.g. the sura or the foot (namely the foot sole turned inward excessively relative to the longitudinal axis of the foot), the one-sided lowering of the pelvis, the wrong anterior-posterior attitude of the pelvis or the differently flexible Achilles tendons, belong to anatomically questionable parts (Fredricson, 1996).

[1] 28,000 – 29,000 vertical take-offs were calculated with a high jumper during a detailed analysis of one athletic season.

Actually, the pronation of the foot causes many problems. With the normal position, the movement automatically starts at the moment when the foot sole, together with the subsequent movement of the ankle joint hits the platform. This extensive movement tends to be the cause of a considerable number of problems.

The position on one leg as with the run or jump, when one leg is in contact with the platform and the central gluteus maximum is weak or lacks control over the position of the pelvis, leads to the lateral lowering of the pelvis and thus to a significant lowering of the support leg.

A deformation of the kneecap causes most of the problems. The excessive utilization of one side of the body as well as the activities performed in the course of the relatively long static phase of the jump result in yaw instability (Fredricson, 1996).

An inflexible Achilles tendon may be the primary cause of the LL problems. The highly-strung Achilles tendon loses its compensation mechanism by reason of the exaggerated pronation and the resulting rotation may cause LL injuries.

General recommendations for performing a demanding sports training of athletes-high jumpers resulting from the long-term study are as follows:

- *to take advantage of as many training means as possible* in connection with the training content and the conditions in which training activities take place;
- *the athletes' adaptation to high values of reaction forces at the take-off* should correspond mainly with morphological, physiological, biomechanical and health standards;
- *the optimum amount of training strain* and the compliance with suitable interrelationship of volume and intensity should correspond with the level of a person's performance;
- *as for the development of performance, to pay attention to the optimum alternation of strain and rest* – not only used-up energy reserves are restored, but also new energy reserves exceeding initial values are created in the rest phase, and
- t*o take advantage of exercises to develop all-roundness*, the inclusion of which in the training is necessary and does not result from the kinetic content of specialization, but which may support it.

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PROCJENA STANJA LOKOMOTORNOG SUSTAVA SKAKAČA U VIS U PREVENCIJI ZDRAVSTVENIH PROBLEMA

Sažetak

Uvod

Preduvjet za uspješno izvođenje kompleksnih kinetičkih struktura skoka u vis je sposobnost podnošenja visoko intenzivnih fizičkih napora koje nameće, između ostaloga, i teške zahtjeve na pripremljenost i funkciju lokomotornog sustava. U današnje se vrijeme, odraz u atletskim skakačkim disciplinama izvodi vrlo eksplozivno – kratkim i snažnim kontaktom s podlogom (t_c = 0,15-0,22 s), stoga se i pregibanje koljena odrazne noge smanjuje. Koljeno je u skoku takvom tehnikom manje opterećeno, ali se opterećenje povećava na drugim dijelovima lokomotornog sustava koji sudjeluju u pokretu.

Nakon više od dvadesetogodišnjeg promatranja domaćih, ali i stranih skakača u vis, može se reći da se većina ozljeda dogodi neočekivano, bez upozorenja te da ih ne karakterizira znatna bol koja je obično povezana s ozbiljnim ozljedama. Te ''prilično čudne'' ozljede tema su ovog članka.

Morfologija noge utječe na stanje i funkcionalnost posturalnih mišića donjih ekstremiteta i/ili također može utjecati na stanje mišićnih skupina i zglobova u donjem dijelu trupa. Pridalova (2002) tvrdi da su donji ekstremiteti ograničavajući faktor za maksimalnu sportsku uspješnost u skoku u vis.

Razlike u anatomskoj strukturi donjih ekstremiteta često se mogu vidjeti u skakača u vis, a te razlike, kada se zanemare, mogu prouzrokovati komplikacije u kasnijem tijeku sportske karijere. Uzmu li se u obzir velik volumen i intenzitet opterećenja, a stoga i velika naprezanja koja atletičarevo tijelo mora podnijeti premda su nejednako raspoređena, nepažnja u najranijoj fazi sportske karijere može rezultirati trajnim ozljedama.

Cilj je ovog rada otkriti i analizirati zdravstvene probleme lokomotornog sustava vrhunskih skakača u vis koji mogu biti prouzrokovani njihovim intenzivnim aktivnostima.

Rezultati

Učestalost pojavljivanja zdravstvenih problema u 47 promatranih skakača u vis ($n_{muškaraca}$ = 29; $n_{žena}$ = 18) bila je visoka.

Da bi se utvrdilo stanje lokomotornog sustava ispitanika, koristio se upitnik. Ispitivani sportaši u upitniku su ukratko opisali probleme i ozlijeđene dijelove tijela. Ova je metoda istraživanja odabrana kako bi potvrdila i upotpunila podatke koji su dobiveni putem invazivnijih tehnika ispitivanja (*In-Depth Interview i Focus Group Discussion*).

Prema dijelu lokomotornog sustava skakača u vis koji je bio ozlijeđen dobiveni su rezultati podijeljeni u sedam dijelova tijela (stopalo, potkoljenica, koljeno, natkoljenica, zdjelični pojas, kralješnica i ostalo) te su podaci računalno obrađeni.

Utvrđeno je da je najviše zdravstvenih problema bilo s odraznom nogom, s lumbalnim i torakalnim dijelom kralješnice, koljenom odrazne noge te s Ahilovom tetivom.

Rasprava i zaključak

Na temelju vrednovanih protokola provedenih intervjua s vrhunskim skakačima u vis te sagledavanjem izmjerenih vrijednosti sila koje se pojavljuju u skoku u vis, može se zaključiti da je najviše ozljeda lokomotornog aparata uzrokovano jednim ili kombinacijom dvaju ili više sljedećih faktora:

- visokim vrijednostima reaktivnih sila pri odrazu
- neadekvatnim trenažnim opterećenjem
- neuravnoteženim kondicijskim treningom (osobito kod početnika)
- nepravilnom tehnikom odraza
- anatomskim predispozicijama za ozljeđivanje.

Opće preporuke za provedbu zahtjevnih sportskih treninga skakača u vis koje su rezultat našeg dugogodišnjeg istraživanja glase:

- *Iskoristiti što više različitih trenažnih podražaja* koji se razlikuju prema trenažnim sadržajima i uvjetima u kojima se trening provodi.
- *Adaptacija sportaša na visoke vrijednosti reaktivnih sila pri odrazu* trebala bi odgovarati morfološkim, fiziološkim, biomehaničkim i zdravstvenim standardima.
- *Optimalna količina trenažnog napora* i poštovanje odgovarajućeg međusobnog odnosa volumena i intenziteta trebala bi odgovarati razini sportaševe uspješnosti.
- *Pri unapređenju izvedbe, paziti na optimalnu izmjenu napora i odmora* – ne samo da se za vrijeme odmora nadoknađuju potrošene rezerve energije, već se za vrijeme odmora stvaraju energetske rezerve koje premašuju prvotno stanje tih energetskih supstancija.
- *Iskoristiti vježbe kojima će se postići opća kondicijska pripremljenost* koja je potrebna za kvalitetan trening i o kojoj ne ovisi razina kinetičke specijalizacije, ali može pomoći njezinu unapređenju.