INTRODUCTION

The overall injury rate in tennis varies greatly from 0.04 injuries/1000 hours to 21.5 injuries/1000 hours of playing tennis depending on injury definition (Pluim et al., 2006). In the majority of investigations at junior level, elite junior players have been the population studied, mostly during tournaments (Kibler & Safran, 2005). The more an athlete is exposed for tennis and other sports, the higher the frequency of injuries according to Kibler and Safran (2005). Recreational junior players experience relatively few injuries (Hutchinson et al., 1995; Kibler & Safran, 2005). Pluim et al (2006) found only three investigations on injury risk factors in tennis and these studies have a number of limitations. Many potential injury risk factors have been discussed in the literature. The majority of these have not been verified to be risk factors, though.

Muscle imbalance in terms of changes in strength and flexibility, can alter joint biomechanics and lead to decreased maximal force output (Kibler & Safran, 2000). Tennis players often present with a decreased internal rotation of the shoulder joint and an increased external rotation of their dominant side, which may result in clinical implications in terms of injuries (Chinn et al., 1974; Chandler et al., 1990; Ellenbecker et al., 1996; Kibler et al., 1996; Ellenbecker et al., 2002; Vad et al., 2003; Schmidt-Wiethoff et al., 2004). Elite junior tennis players with symptoms from their dominant shoulder joint showed a decreased internal shoulder rotation compared to asymptomatic players of the same age and level (Vad et al., 2003). Players with back pain from the lumbar spine showed a decreased internal rotation of the leading hip joint as well as deficits in extension of the lumber spine (Vad et al., 2003).

Oversized head, heavier, stiffer, more tightly strung rackets, incorrect grip size and increased vibration have been associated with problems like “tennis elbow” (Kamien, 1989; Pluim et al., 2006). However, this is a fairly rare syndrome in young tennis players (Pluim et al., 2006).

A significantly lower injury rate has been reported by tennis players when playing on clay or synthetic sand when compared with playing on hard court (Nigg & Segesser, 1998).

The purpose of the present study was to evaluate potential intrinsic as well as extrinsic injury risk factors in junior tennis players.

METHODS

Subjects

A prospective cohort design was used involving junior tennis players from a Swedish tennis club with approximately 100 junior members (12-18 years of age). Playing tennis at least twice a week and no injuries that influenced tennis at the start of the study were regarded as inclusion criteria. All junior members in this tennis club were invited to participate in the study. Seventy-five players accepted to participate. Out of these 75 players, 65 players (40 boys and 25 girls) fulfilled the inclusion criteria and gave their informed consent to participate. The study was approved by the ethical committee at the Karolinska University Hospital (Dnr 98/198).

Questionnaire

In 1998 Safran constructed a tennis questionnaire which has been shown to be both valid and reliable (Safran, 2000). This questionnaire consists of five parts; identification data, playing and training history, equipment and injury history. We have used this questionnaire in a modified version. Eighteen out of the 60 questions were removed and five questions were modified. The following new question was added: Do you have any injuries today that prevent you from playing 100%? The questions that were used from the original Safran´s questionnaire have been translated according to the guidelines for the process of cross cultural adaptations of self-report measures (Beaton et al., 2000). The translation into Swedish was found to be satisfactory. The used questionnaire contained questions based on the following possible injury risk factors: age, sex, Body Mass Index (BMI), experience of playing tennis, single handed/double handed backhand, dominant arm, previous injuries, exposure to tennis, participation in other sports, stretching routines, playing surface and equipment.

Exposure to tennis

In the questionnaire the player was asked to report the number of hours per week that he/she participated in tennis including practise and matches. If the player did not play the usual average hours per week he (or she) informed the principal investigator (PI) about this. Furthermore, the PI contacted each player every three months to secure correct information about the exposure to tennis, possible injuries related to tennis or other sports as well as illness or absence from playing tennis. These data were then used to calculate time of exposure and injury incidence during the two year survey.

Measurements

Baseline assessments were performed by the PI. All tests but one, used in the musculoskeletal testing procedure, were based on previous research (Ekstrand et al., 1982; Haker & Lundeberg, 1990; Greene & Heckman, 1994; Roetert et al., 1995; Kibler et al., 1996; Jonson & Gross, 1997; Ageberg et al., 1998; Jackson et al., 1998; Kibler et al., 2002; Marcovic et al., 2004) and were mainly chosen because they were easy to perform in a clinical setting. The tests are presented in table 1. Range of motion was measured by either a standard goniometer (31.5cm) or an inclinometer (Myrin ™ OB goniometer). Every second player started the measurements on the right side and every second on the left. All measurements were performed once except for muscle strength and agility, which were performed three times, and balance, twice. The best result was recorded. In the medicine ball tests 32 players (60%) participated.

Active rotation of the thoracic and lumbar spine was measured with the player sitting on a stool with his/her legs locked into the stool legs. The stool was placed in the centre of a large 180° protractor, which was drawn on a large wooden platform. The player was holding onto a long stick with one hand on each side. The stick was placed on the shoulders. The player performed an active rotation of the trunk without any movement of the pelvis. The angle on the protractor was recorded.

The Standing on One Leg Eyes Closed (SOLEC) test was used to evaluate balance/postural sway. The player stood barefoot on one leg in a circle with a diameter of 0.5 m. The arms of the player were kept crossed over the chest and the “free” leg was kept in approximately 90° of knee flexion without touching the "standing" leg. The hip of the “free” leg was kept straight. The goal of the SOLEC test is to be able to stand in this position for 60 seconds. The player was allowed to move the foot within the circle. Three trials on each leg were carried out and the longest time was recorded. This test has a reliability of 0.63-0.70 (Faltstrom & Werner, personal communication).

The Hexagon test was used to evaluate agility while measuring the time it takes to jump three laps in and out of a Hexagon figure (Roetert et al., 1995). This test was used in a slightly modified way. The player started with the side towards one of the lines of the Hexagon, while in the original test the player started the test by facing one of the lines.

Kibler et al (2002) used three positions of the arms in the Lateral Scapular Slide test (LSS). In the present study only the third position was used. Winging of the scapula was determined by palpating the medial border of the scapula for displacement from the thoracic cage.

In general, reliability studies regarding range of motion measured with a goniometer have shown acceptable reliability and intratester reliability is generally better than intertester reliability (Ekstrand et al., 1982; Jonson & Gross, 1997). The PI have performed an intra- and intertester reliability of some of the tests that lack reliability testing in the literature i.e. flexion of the shoulder joint, scapular winging and anterior drawer of the ankle joint, the Lachman test, thoraco-lumbar rotation and the slightly modified Hexagon test. Almost all other tests in the test battery are reported elsewhere and have shown to be reliable (Greene & Heckman, 1994; Ellenbecker et al, 1996; Jonson & Gross, 1997; Ageberg et al, 1998; Jackson et al, 1998; Stockbrugger & Haennel, 2001; Kibler et al, 2002; Marcovic et al, 2004).

New dichotomous variables were created in order to determine if differences between the dominant and non-dominant side in terms of range of motion, flexibility, functional tests, and grip strength could be identified as injury risk factors. Differences regarding range of motion and flexibility, were calculated as positive (dichotomous coding as 1) if there were more than ten degrees difference between the dominant and non-dominant side (Norkin & White, 2003). When it comes to functional tests and grip strength a side-to-side difference of more than ten percent was regarded to be of clinical relevance.

Injury definition

In the present study an injury was defined as an injury if it was impossible to participate in regular tennis training or playing matches during at least one occasion, a time loss injury (Fuller et al., 2006). Recurrence was defined as an injury of the same type and at the same site that occurred within 12 months after the index injury. Injury severity was defined as the number of days from the date of injury to the date of returning to full participation in training or match (Fuller et al, 2006). Definitions of injury classification, location of injury, type of injury and diagnosis were based on the **Orchard Sports Injury Classification System (OSICS)** (Fuller et al., 2006). Back injuries were categorised between upper and lower back. Lower back injury was defined as low back pain and upper back injury as upper back pain. A traumatic injury was defined as an injury caused by a trauma, while an overuse injury was defined as an injury with a gradual onset and not caused by any trauma (Taimela et al., 1990).

Injury registration

All injuries related to tennis were registered prospectively during a two-year period. Injuries occurring during other activities than tennis were not included in the present investigation. The players received both written and oral information about the definition of injury and injury reporting procedure. Every third month the players were contacted by the PI, to make sure that they had not forgotten to report any injuries. Training habits were registered by the PI on a regular basis.

The tennis players were informed to contact the PI, if they were injured. The PI and an orthopaedic surgeon (when needed) performed the first time clinical examination of the injured player. When a player was injured at other places than their home town, a first time clinical examination was carried out by another person and the injured player had a second examination performed by the PI when back in his/her home town. The PI filled out an injury form, which included date of injury and return to full participation in tennis, new or recurrent injury **(**injury to the same site within 12 months)**,** type and localisation of injury, mechanism of injury, diagnosis, traumatic/overuse injury, training or match and playing surface.

Statistics

Means and standard deviations (SD) for continuous variables and cross tables for categorical variables were calculated to describe and compare injured with uninjured players. Statistical comparisons were done with Student's t-test and Chi 2 analysis for categorical variables. The influence of potential predictor test variables (x-variables; see table 1 and 2 and differences between dominant and non-dominant side in functional tests, grip strength, flexibility tests, and range of motion tests) on the risk for an injury or not, injury to the upper extremity, lower extremity and the back (y-variables) were first analysed by univariate logistic regression. Because of the large amount of variables, we divided them into four different categories and each category was tested separately in the logistic regression model for an injury or not, injury in the upper limb, lower limb and the back. The categories were 1) variables from the questionnaire, 2) range of motion test variables and the stability test variables from the musculoskeletal testing protocol, 3) strength, agility and balance test variables from the muscular skeletal testing protocol, 4) the difference between dominant and non-dominant side for all testing variables in the musculoskeletal testing protocol. The risk factors that were significant (two tailed p-value less than 0.1) were then analysed in a forward stepwise logistic regression model. P-value for entering the model was set at 0.05 and for removal 0.10. Results are presented as odds ratios (OR) with 95% confidence intervals (CI). Due to skewed distributions, some of the continuous variables in the testing protocol were dichotomized based on percentiles; values below the 25th percentile or above the 75th percentile; values between the 25th and 75th percentile (table 2). In tables 3-6 the risk factors are presented as well as all variables (from the four different analyses) with unadjusted OR with p-values less than 0.1 from the univariate regression model in the same table. The unadjusted OR gives more information about those risk factors that just failed in the forward stepwise regression analysis. These risk factors may be seen as "tendency" for an injury.

RESULTS

Subjects

Due to various reasons such as ceased playing tennis or played less than two times per week (n=5), changed tennis club (n=3), moved abroad (n=2), ten players were referred to as drop-outs and were not followed during the two year injury registration period. Therefore, the results are based on 55 players (35 boys and 20 girls).

Out of 55 players 32 players (60%) performed the medicine ball tests. Twenty-two out of 39 players from the injured group and 10 out of 16 players from the uninjured group performed these tests. This means that 57% of the injured players and 62% of the uninjured players carried out these tests.

Demographic data of injured and uninjured players

One hundred injuries, 65 new and 35 recurrent injuries, were sustained in 39 players. Twenty-five boys sustained 73% of all injuries and 14 girls sustained 27% of the injuries. For more information about the injuries, please see tables 7, 8 and 9 as well as figure 1.

Table 2 shows demographic data for injured and uninjured players. All data were collected at baseline except for tennis play per week and total play per year which were based on the two years survey. There were significant differences between the uninjured and injured group in single play ($p<0.0001$) and total play per year ($p=0.016$).

Inter- and Intratester reliability

The inter- and intratester reliability regarding the tests that was undertaken by the PI showed the following ICC values: flexion of the shoulder joint 0.89 (inter) and 0.73-0.96 (intra), rotation of the thoraco-lumbar spine 0.88-0.93 (inter) and 0.64-0.92 (intra), winging of the scapula 0.76-0.92 (inter) and 0.64-0.87 (intra), the Lachman test 0.46 (inter) and 0.70 (intra), anterior drawer of the ankle joint 0.47 (inter) and 0.45 (intra) and the Hexagon test 0.64 (intra).

Injury in general

Table 3 presents the variables that were found to be injury risk factors in general.

Injury to the upper extremity

Table 4 presents the variables that were found to be injury risk factors to the upper extremity.

Injury to the lower extremity

Table 5 presents the injury risk factors to the lower extremity. The injured players tossed between 1-1.6 meters shorter than the uninjured players in all the four medicine ball tests (n.s.)

Back pain

Table 6 presents the variables that appeared to be risk factors for back pain. Players with back pain had less range of motion in many joints, although the results were not significant except for lateral flexion of the neck at the dominant side.

Playing surface

There were no significant differences in terms of injuries sustained while playing on hard court compared to playing at clay. Seventy percent (boys 67%, girls 78%) of all injuries occurred when playing on hard court surfaces and 24% occurred while playing on clay (boys 25%, girls 22%). The players reported that they were playing on hard court on average 70% of their total playing time over the year and on clay 30%. This gives us an index of sustaining an injury while playing on hard court of 1.0 and while playing on clay 0.8. Injury localisation were the same except for more injuries to the lower extremity on hard court than on clay, 56% and 38%, respectively, although not significant.

DISCUSSION

The main finding of the present investigation was that a previous injury regardless of body location was found to be an injury risk factor. In addition, we also found that a previous injury to the back and playing tennis more than six hours per week were identified as risk factors for back pain.

Earlier studies on other sports have shown strong evidence that a previous injury increases the risk of a recurrent injury or a new injury (Van Mechelen, 1992; Van Mechelen et al., 1993; Murphy et al., 2003). This finding has led to a general suggestion, although not evidence based that the injury risk increases with inadequate rehabilitation. In our opinion a young player may benefit by seeing a professional therapist with good knowledge of the biomechanics and profile of demands in tennis before considering return to tennis after an injury. It is of utmost importance to include sufficient time for recovery prior to a gradual return to playing tennis is allowed. Furthermore, functional performance tests tailored for tennis players may to some extent predict a "safe" return to sport. However, hitherto there is no consensus on what specific tests that should be used for evaluating tennis players. To our knowledge no studies have been performed about this.

Pluim et al. (2006) reported exposure to tennis to be a risk factor for injuries in general. In our study we found that exposure to tennis was a risk factor for sustaining an injury to the back. In addition, the injured players in the present study played more than double the amount of single sessions a week and played almost the double amount of hours per year than the uninjured group. Furthermore, the less number of years of playing tennis the higher the risk of injury to the upper extremity. The reason for this finding is difficult to explain, though. One explanation could be that these junior players have not yet learnt a good stroke technique. This may be true for the service motion, the most difficult and powerful stroke in tennis, which may result in disturbance in the kinetic link (Kibler, 1995). If there are any deficits in strength anywhere in the kinetic chain, there will be an increased load of other joints and muscles, which may lead to increased injury risk. The kinetic chain is crucial for developing power in the strokes (Kibler, 1995). Fifty-four percent of the total force is developed in the leg/hip/trunk link and 21% in the shoulder. Many young tennis players present with weak lower extremity muscles and therefore do not have sufficient strength to hit the ball the way the older players do (Kibler, 1995). They must instead rely on biomechanical efficiency to hit effective shots. However, we did not find any differences in leg strength between injured and uninjured players when measured with the one-leg hop test for distance and the vertical hop test.

Although not significant, players with lower extremity injuries tossed 1.0-1.6 meters shorter in all the medicine ball tests. This may stress the importance of a good balance in terms of muscle strength between the lower and upper body (Chandler et al., 1998). Muscle weakness of the trunk and upper extremity may put high demands on the lower extremity and thereby an increased injury risk. Roetert et al (1996) found significant correlations between medicine ball tosses (reverse, overhead, backhand, forehand) and isokinetic muscle torques of the trunk muscles during flexion and extension. Thus, this may indicate that medicine ball tosses are likely to put stress on the strength of the trunk. Stockbrugger and Haennel (2001) however, showed that the reverse medicine ball toss was correlated to the vertical hop test and therefore suggested that this test may reflect the movement pattern of the total body.

Several authors have discussed tennis generated musculoskeletal maladaptations such as differences in range of motion and muscle strength between the dominant and non-dominant side as being potential injury risk factors (Knapik et al., 1991; Young et al., 1996; Chandler et al., 1998; Kibler & Safran, 2000). Renkawitz et al (2006) found distinct neuromuscular imbalances between the right and left erector spinae at the second and fourth vertebrae of the lumbar spine during maximum voluntary trunk extension among tennis players with low back pain. Players without low back pain did not show any such imbalances. Interestingly, they also found that the direction of electromyographic (EMG) imbalance was amazingly closely related to handedness. Nearly all right handed players showed significant lower integrated EMG (IEMG) measures on the left side of erector spinae, and left handed players showed lower IEMG on the right side. The authors state that these results suggest that asymmetric trunk loading as it is in tennis and other racquet sports induce neuromuscular imbalances Renkawitz et al., 2006). However, the question whether these changes is a cause or a result of low back pain remains unanswered. In the present study, players with a side-to-side difference in total shoulder rotation, and a muscle strength difference of more than 10 % between forehand and backhand medicine ball tosses showed a tendency to back pain. Players with a side-to-side difference in scapular winging showed a tendency to upper extremity injuries.

A decrease in internal rotation of the shoulder joint has been reported to be associated with both age and number of years in tennis and may further be a risk factor for injury (Ellenbecker et al., 1996; Kibler et al., 1996; Vad et al., 2003). In our study we did not find any differences in range of motion of the shoulder joint between injured and uninjured players. One reason may be the young age of our players and that they sustained relatively few shoulder injuries. However, we found that players who sustained injuries to the lower back presented with decreased range of motion in several joints including the shoulder joints, compared to uninjured players, although only the dominant and non-dominant lateral flexion of the neck was found to be significant.

Chandler et al (1990) found a decrease in the sit and reach test in tennis players compared to athletes in other sports. In the present investigation we did not find any difference in sit and reach test between injured and uninjured players. However, we found a decrease in the non-dominant lateral flexion of the neck in players with back pain. This may force the player to increase the extension of the back, in particular lumbar lordosis, at early cocking and cocking phase in the service motion leading to an increased load of joints, ligaments and muscles of the back and thereby a risk of being injured. As the movements of the cervical spine in the early cocking and cocking phase in the service are a combination of lateral flexion of the neck at the non-dominant side, rotation and extension of the dominant side, we do not know whether this range of motion was even more decreased in players with back injuries, since combined movements were not tested. Young et al (1996) hypothesised that the cervical spine may be involved in force generation during the throwing or tennis serving motions through the mechanism of torque-counter torque as well as of the lower back. However, this is an area which needs to be investigated more thoroughly.

Imbalance between muscle strength and flexibility may be risk factors for injury as specific strength and flexibility imbalances have been reported to be associated with lower extremity injuries in female collegiate athletes, tennis included (Knapik et al., 1991). In the present investigation, we did, however, not find any such imbalances in the players with lower extremity injuries. We found that the players who regularly performed stretching exercises "in general" had sustained a lower extremity injury more often than players who did not stretch. This is in agreement with a study by van Mechelen et al. (1993). In accordance, a systematic review about the efficacy of static stretching as part of a warm-up for the prevention of exercise-related injuries, showed moderate to strong evidence that static stretching does not reduce overall injury rates. However, the same review report that there is preliminary evidence that static stretching may reduce musculotendinous injuries (Small et al, 2008).

Some limitations of the present study need to be addressed. The sample size was somewhat small due to that we only included junior players from one typical tennis club and the participation was voluntary. Furthermore, some members did not fulfil the inclusion criteria by being healthy and uninjured at the start of the study. We had ten players (15%) that dropped out. However, these ten players did not differ from the other 55 players that completed the investigation in any parameters that we have studied. According to Bahr and Holme (2003) when identifying injury risk factors in sports, 20-50 participants are needed for a moderate to strong association and 200 for a small to moderate association.
Based on the literature when it comes to power calculation we performed an 80% power analysis for the medicine ball toss performance and found quite large differences (1.6 meters - 1.0 meters) between players who sustained an injury to the lower extremity and those who did not sustain any lower extremity injury. For this variable/factor the power analysis showed a need for 279 players. On the other hand, we also performed a power analysis using an identified significant injury risk factor, earlier injuries for injuries in general, which showed a power of over 0.99. These examples really show how difficult it is to make a proper power analysis in this type of research.

Those players that reported a previous injury regardless of injury location showed a higher number of injuries during the two year registration period. Injury to the back was the only previous injury location that was identified as a risk factor for a new or recurrent injury at the same location. The young players had, however, some problems to describe their previous injuries in detail in the open questions, which is a study limitation. Therefore, a well structured interview may probably have been better in order to get a more complete picture of their previous injuries.

Recall bias has been reported to be a major problem when using a self reporting study design (Junge & Dvorak, 2000). We were in contact with our players every third month in order to make sure that no injuries were forgotten to be reported. The PI, who worked at a physical therapy clinic in connection with the tennis arena, had a close collaboration with both the tennis coaches and the players throughout the entire study period (two years). This may at least to some extent prevent recall bias.

In light of this investigation we conclude that a previous injury regardless of body location was found to be an injury risk factor. Furthermore, a previous injury to the back and playing tennis more than six hours per week were identified as risk factors for back pain.

Perspective

It is well documented in the literature that physical activity during growth plays an important role in order to prevent injuries and diseases later on in life, for instance osteoporosis, diabetes mellitus, obesities and cardiovascular diseases. Participating in sports also is of great value from a social and psychological point of view. In the growing individual sports performance also is of importance from a behavioural perspective. Unfortunately, physical activity and sports may lead to injuries. Therefore, injury preventative strategies need to be conducted, and a successful prevention program should be based on both intrinsic and extrinsic risk factors. To our knowledge, this is the only study hitherto on injury risk factors in young tennis players.

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Table 1. The tests within the test battery.

Test parameters	Description
Range of motion	Rotation and lateral flexion of the neck
	Rotation of the thoracic/lumbar spine
	Flexion, internal- and external rotation of the shoulder joint
	Flexion and extension of the elbow joint
	Pronation and supination of the forearm
	Flexion and extension of the wrist joint
	Ankle dorsiflexion with knee extended and knee flexed
Muscle flexibility	Sit and reach test
	Thomas test
	Flexibility of the hamstrings
Scapular dyskinesia	Lateral Scapular Slide test
	Scapular winging
Muscle strength	Medicine ball tosses over the head, reverse, backhand and forehand
	Push ups
	Sit ups
	One-leg hop for distance
	Vertical jump on two legs
Agility	Hexagon test
Balance/postural sway	SOLEC test
Joint stability	Lachman test
	Anterior drawer test of the ankle joint

Table 2. Demographic data for injured and uninjured players based on baseline measurements except for single and double play per week and total play a year, which was calculated during the two year survey.

		Injured group n=39	**Uninjured group n=16**
Age	mean (SD)	15.5 (3.17)	15.1 (1.84)
BMI	mean (SD)	20.3 (2.20)	19.5 (3.02)
Boys/girls	%	64/36	63/37
Single/Double backhand	%	5/95	13/87
Right/Left dominance	%	95/5	87/13
Single play* hours per week	mean (SD)	8.8 (6.8)	3.8 (1.9)
Double play hours per week	mean (SD)	1.6 (1.79)	1.5 (1.33)
Total play a year * hours/year	mean (SD)	446 (331.7)	246 (119.4)
Years of tennis play	mean (SD)	8.6 (3.39)	8.0 (2.64)

*There were significant differences between the injured and uninjured group in single play ($p<0.0001$) and total play per year ($p=0.002$)

Table 3. Injury risk factors in general. Both unadjusted and adjusted OR is presented**.**

Injury risk factors	**Unadjusted OR** **OR, CI, p-value**	**Adjusted OR** **OR, CI, p-value**
Previous injury in general	10.0 (2.3-42.6), p=0.002	8.8 (2.1-37.0), p=0.003
Total play a year	1.0 (1.00-1.01), p=0.032	n.s.
Single and double play/week **(>6 vs <6** hours/week)	3.0 (0.9-9.9), p=0.076	n.s.

n.s. = non significant

Table 4. Injury risk factors of the upper extremity. Both unadjusted and adjusted OR is presented.

Injury risk factors	**Unadjusted OR** **OR, CI, p-value**	**Adjusted OR** **OR, CI, p-value**
Years of tennis play	0.8 (0.6-1.0), p=0.041	0.7 (0.6-1.0), p=0.017
Different shoes on different surfaces	0.3 (0.1-1.0), p=0.053	0.2 (0.04-0.81), p=0.026
Difference between dominant and non-dominant side in dorsal flexion of the wrist	3.1 (0.9-11.0), p=0.080	n.s.
Differences between dominant and non-dominant side in scapular winging	2.8 (0.9-9.2), p=0.088	n.s.

n.s. = non-significant

Table 5. Injury risk factors of the lower extremity. Both unadjusted and adjusted OR is presented.

Injury risk factors	**Unadjusted OR** **OR, CI, p-value**	**Adjusted OR** **OR, CI, p-value**
Stretching before and after tennis play	11.4 (1.3-98.6), p=0.027	9.4 (1.0-89.8), p=0.052
Previous injury in general	18.6 (2.2-157.5), p=0.007	16.4 (1.8-144.5), p=0.012
Total play per year	1.0 (1.0-1.0), p=0.017	n.s.
Dominant hip flexor flexibility	1.1 (1.0-1.2), p=0.066	n.s.
Non-dominant hip flexor flexibility	1.1 (1.0-1.2), p=0.066	n.s.
Non-dominant Anterior Drawer test of the ankle joint	0.3 (0.1-1.2), p=0.091	n.s.
Backhand medicine ball toss	0.7 (0.4-1.0), p=0.068	n.s.
Difference between dominant and non-dominant side in internal rotation of the shoulder joint	0.2 (0.1-0.7), p=0.015	n.s.
Difference between dominant and non-dominant side in dorsiflexion of the wrist	5.2 (0.1-1.9), p=0.023	n.s.

n.s. = non significant

Table 6. Injury risk factors of the back. Both unadjusted and adjusted OR is presented.

Injury risk factors	**Unadjusted OR** **OR, CI, p-value**	**Adjusted OR** **OR, CI, p-value**
Single and double play **(>6 vs <6** hours/week)	16.6 (2.0-139.1), p=0.010	1.3 (1.3-99.6), p=0.029
Previous injury of the back	7.8 (2.0-30.5), p=0.003	4.7 (1.1-20.5), p=0.039
Lateral flexion of the neck at the dominant side	0.8 (0.7-1.0), p=0.017	0.8 (0.7-1.0), p=0.017
Racket length (normal/extra length)	10 (1.25-50.0), p=0.028	n.s.
Lateral flexion of the neck at the non-dominant side	0.9 (0.8-1.0), p=0.051	n.s.
Tennis hours/year	1.0 (1.00-1.01) p=0.08	n.s.
Participating in other sports	4.7 (0.9-23.7) p=0.06	n.s.
> 10 degrees difference between dominant and non dominant total shoulder rotation	3.7 (0.8-17.5) p=0.1	n.s.
> 10 degrees difference between dominant and non-dominant side in flexion of the shoulder joint	3.2 (0.8-13.1), p=0.098	n.s.
> 10 degrees difference between dominant and non-dominant side in extension of the elbow joint	3.7 (0.8-17.5), p=0.098	n.s.
> 10 % difference between forehand and backhand medicine ball tosses	4.1 (0.8-20.4) p=0.09	n.s.

n.s. = non significant

Table 7. Information about the distribution of new and recurrent injuries (n) and incidence of injuries (number of injuries/1000 playing hours). CI = Confidence Interval.

	Boys	Girls	All players
New injuries, n Injury incidence (CI) Injured players, n	45 1.1 (0.75-1.36) 19	20 0.5 (0.26-0.67) 11	65 1.5 (1.15-1.89) 30
New and recurrent injuries, n Injury incidence (CI) Injured players, n	73 1.7 (1.32-2.10) 25	27 0.6 (0.39-0.87) 14	100 2.3 (1.88-2.80) 39
Upper extremity injuries, n Injury incidence(CI) Injured players, n	18 0.5 (0.25-0.65) 13	6 0.1 (0.03-0.25) 4	24 0.6 (0.36-0.82) 17
Lower extremity injuries, n Injury incidence (CI) Injured players, n	37 0.8 (0.57-1.12) 18	14 0.3 (0.16-0.50) 10	51 1.2 (0.84-1.50) 50
Trunk injuries, n Injury incidence (CI) Injured players, n	17 0.4 (0.21-0.59) 10	7 0.2 (0.04-0.29) 4	24 0.6 (0.34-0.79) 14
Traumatic injuries, n (% of all injuries per gender)	33 (45.2)	12 (44.4)	45 (45.0)
Overuse injuries, n (%)	40 (54.8)	15 (55.6)	55 (55.0)

Table 8. The most commonly registered injuries are presented as the number of new and recurrent injuries and new injuries separately.

Diagnosis	New and recurrent injuries	New injuries
Ankle distortion	18	8
Muscle strain in the lower back	14	4
Groin muscle strain	5	5
Elbow tendinopathy	4	3
Rotator cuff tendinopathy	3	2
Lumbar facet joint sprain	3	1

Table 9. Injury severity. Number of injuries (and %) in each category are presented for boys and girls.

	Minimal **1-3 days**	**Mild** **4-7 days**	**Moderate** **8-28 days**	**Severe** **> 28 days**
Boys	6 (8.2)	15 (20.5)	22 (30.1)	30 (41.1)
Girls	3 (11.1)	2 (7.4)	9 (33.3)	13 (48.1)
Boys and girls	9 (9.0)	17 (17.0)	31 (31.0)	43 (43.0)

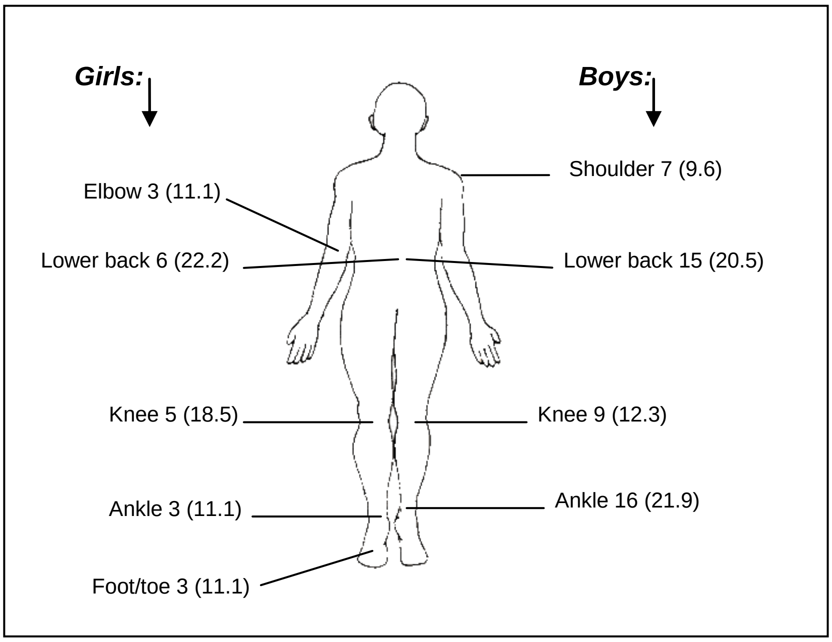

Figure 1. Anatomical localization of the most common injured body parts, n (%), in both boys and girls, respectively.