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Risk factors for musculoskeletal injuries in elite junior tennis players: a systematic review

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ABSTRACT

The objective was to systematically review the literature on risk factors and prevention programs for musculoskeletal injuries among tennis players. PubmedMedline, Embase, CINAHL, Cochrane, SportDiscus were searched up to February 2017. Experts in clinical and epidemiological medicine were contacted to obtain additional studies.

For risk factors, prospective cohort studies (n > 20) with a statistical analysis for injured and non-injured players were included and studies with a RCT design for prevention programs. Downs&Black checklist was assessed for risk of bias for risk factors. From a total of 4067 articles, five articles met our inclusion criteria for risk factors. No studies on effectiveness of prevention programs were identified. Quality of studies included varied from fair to excellent.

Best evidence synthesis revealed moderate evidence for previous injury regardless of body location in general and fewer years of tennis experience for the occurrence of upper extremity injuries. Moderate evidence was found for lower back injuries, a previous back injury, playing >6hours/week and low lateral flexion of the neck for risk factors. Limited evidence was found for male gender as a risk factor.

The risk factors identified can assist clinicians in developing prevention-strategies. Further studies should focus on risk factor evaluation in recreational adult tennis players.

ARTICLE HISTORY
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KEYWORDS
Sports; prevention; athletes; sports medicine; workload

1. Introduction

Tennis is a popular sport, with more than 75 million participants in nearly 215 countries("ITF Tennis,"n.d., Oct 13)[r](B. Pluim et al., 2007a). Tennis has a broad appeal, positive health benefits and enhances fitness and wellbeing(Kovacs et al., 2016). However, musculoskeletal injuries occur and can lead to withdrawal from tennis participation(Maffulli et al., 2010). The incidence rate of tennis injuries varies from 0.04 to 3.00 per 1000 hours played, with the highest incidence in the lower extremity, followed by the upper extremity and the trunk (Pluim, Staal, Windler, & Jayanthi, 2006).

In 2006, Pluim et al. performed a narrative review on occurrence, etiology and prevention of tennis injuries(Pluim et al., 2006). Most studies included focused on the epidemiology of tennis injuries. Only three studies investigating risk factors were identified. Older age was found to be a risk factor for tennis elbow(Carroll, 1981; Gruchow & Pelletier, 1979; Kitai, Itay, Ruder, Engel, & Modan, 1986; Priest, Braden, & Gerberich, 1980), but no significant association was found for gender or level of play for the occurrence of tennis injuries (Jayanthi, O'Boyle, & Durazo-Arvizu, 2009).

According to the "sequence of prevention model", it is essential to determine and understand the risk factors (i.e. mechanism) associated with tennis injuries(van Mechelen, Hlobil, & Kemper, 1992). Based on this information, an injury prevention program can be developed in order to mitigate the causes of injury(B. Pluim et al., 2007a; van Mechelen et al., 1992). The aim of the current study is to systematically review the literature on the (intrinsic and extrinsic) risk factors and prevention programs of musculoskeletal injuries in tennis.

2. Methods

2.1 Literature search

Registration in the PROSPERO International prospective register of systematic reviews was performed prior to study initiation (registration number CRD42015026297). This study is reported according to PRISMA guidelines were followed for reporting(Moher, Liberati, Tetzlaff, & Altman, 2014). A systematic search of the available literature was performed in PubMed, EMBASE, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Cochrane Library and SPORTDiscus up to

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Supplementary data can be accessed here.

February 2017. Database specific keywords, similar to the previous systematic review(Pluim et al., 2006), were specified following the next subjects: Tennis, injuries, risk factors and prevention programs. The search was performed by one author (JO), in collaboration with a clinical librarian, using a-priori defined search terms (Supplement 1). Co-authors of this review were additionally asked about internationally known published and/or recently completed and/or submitted studies on risk factor and prevention programs for musculoskeletal tennis injuries up to February 2017.

2.2 Study selection

A study was eligible if it met the inclusion criteria, listed in Table 1. All included studies were imported into a citation database (Mendeley) and duplicates were removed. Titles and abstracts were independently screened, by two reviewers (JO and VG). Full text articles were then independently assessed for eligibility by two reviewers (JO and VG). Additional studies were identified by screening references and contacting clinical and epidemiological experts, according to the inclusion- and exclusion criteria. No disagreements during study selection occurred between the two reviewers (JO and VG).

2.3 Data extraction

One reviewer (JO) extracted the data of included studies; first author's name, year of publication, country, study setting, study population, injury definition, injury specification, incidence, risk factors and preventive implications.

2.4 Quality assessment of included studies

The (modified) Downs and Black checklist assesses both randomized and non-randomized studies and was used for the evaluation of risk factor studies(Downs & Black, 1998). The tool evaluates studies' quality in terms of reporting, external validity, bias, confounding variables and power, comprising a total of 27 items. Based on previous literature, we modified the scale to fit our research question to 14 applicable items (Chudyk, Jutai, Petrella, & Speechley, 2009; Hooper, Jutai, Strong, & Russell-Minda, 2008; Pas et al., 2015).

Quality assessment was performed by three experienced reviewers, including a senior epidemiologist (BS), a sports medicine physician (MM) and a professor in sports traumatology (GK). Two reviewers (MM and JBS) performed the quality assessment of the included studies. If the first two reviewers did not reach consensus, the score of the third reviewer (GK) was decisive.

The items applicable to our research question are shown in Appendix 1. We adapted the following quality levels based on previous literature, using the D&B score; excellent (13–14), good (10–12), fair (8–9) and poor (≤7). Studies with an excellent and good outcome on the D&B score were considered to be of low risk of bias, where fair and poor outcomes were considered to indicate high risk of bias(Chudyk et al., 2009; Hooper et al., 2008; Silverman, Schertz, Yuen, Lowman, & Bickel, 2012). Assessing the risk of bias among studies was performed to consider anticipated variability in either the results or validity of the included studies.

The Cochrane Collaboration's tool was used for the risk of bias for assessment of the randomized controlled trials (RCT) on prevention programs (Higgins, Altman, & Sterne, 2011). Classification was planned: high risk of bias when at least one item was rated as high risk. An unclear risk of bias was assigned when at least one item was classified as unclear risk. A low risk of bias was assigned when all items were rated as having a low risk.

2.5 Best evidence synthesis

Best-evidence synthesis for each risk factor was performed, consisting of five levels of evidence based qualitative analysis(van Tulder, Furlan, Bombardier, & Bouter, 2003)(Reurink et al., 2015). Level of evidence was established for the relationship of each risk factor and the occurrence of musculoskeletal tennis injuries:

- Strong evidence: provided by ≥2 studies with excellent or good quality and by generally consistent findings in all studies (≥75% of studies reported consistent findings)
- Moderate evidence: provided by 1 study with excellent or good quality and/or two or more studies with fair or poor quality and by generally consistent findings in all studies
- Limited evidence: provided by only one study with fair or poor quality
- Conflicting evidence: inconsistent findings in multiple studies (<75% of the studies reported consistent findings)
- No evidence: when no studies could be found

Additionally, the results were approached in a multi factorial model of musculoskeletal injuries(Bahr & Holme, 2003; Meeuwisse, Tyreman, Hagel, & Emery, 2007). The multifactorial approach is used to account for all the factors involved, that is, the internal and external risk factors as well as the inciting event. This accounts for the events leading to an injury situation, as well as a description of whole body biomechanics at time of injury.

Table 1. Eligibility criteria for inclusion of studies.

	Risk factors
Inclusion	Prospective cohort studies involving risk factors for injuries in tennis players (n ≥ 20)(Bahr & Holme, 2003); Statistical analysis includes injured and non-injured players (e.g., logistic regression analysis); Tennis related injury.
Exclusion	Limited to reporting incidence rates for injuries; Investigated an intervention or treatment effect; Was not available as full text; Was not published in English, German, French or Dutch.
Prevention Programs	
Inclusion	Study design was a RCT; Included tennis players of either sex who were at risk of incurring tennis injuries (e.g., playing tennis) Included prevention intervention in comparison with a control or alternative intervention for the prevention of tennis injuries; Study was required to report on the outcome of incidence of a tennis injury.
Exclusion	Participating in an injury rehabilitation program

3. Results

3.1 Study selection

An overview of the study identification process is provided in Table 2. The database search yielded 8479 articles, including 20 articles through reference screening and contacting clinical and epidemiological experts. Duplicate removal resulted in 4067 potentially relevant articles. From those, 3898 abstracts were excluded and 169 full-text articles were screened using the eligibility criteria. A total of 163 articles were excluded, mainly because of the study design (e.g., retrospective cohort studies). As the reference and expert screening did not result in additional articles, 5 studies, all on risk factors for injuries, were included in this systematic review. No prevention studies were identified that met the inclusion criteria. No disagreements occurred during study selection,

3.2 Study characteristics of the risk factor studies

The characteristics of the 5 studies included are summarized in Table 3.

Winge et al. (Winge, Jorgenson, & Lassen Nielsen, 1989) prospectively studied 89 elite players (28 female, 61males) with a mean age of 26 years (range 13–48) for 6 months. Injuries that occurred in connection with training or matches were reported. A statistically significant higher occurrence was reported in males compared to females.

Silva et al. (Silva, Takahashi, Berra, & Cohen, 2002) observed medical appointments, i.e. any consultation and/or treatment given to an athlete during an official junior tournament on-site, in 258 players aged 10 to 18 years for one year.

Hjelm et al. (Hjelm, Werner, & Renstrom, 2012) prospectively studied 55 junior tennis players (35 males, 20 females) between the ages of 10 and 18 years for 2 years. An injury was reported when a tennis player was unable to participate in training or matches at least one occasion. Significant risk factors were a previous injury regardless of body location in general and a lower range of motion for lateral flexion of the neck for the occurrence for a back injury. Players who regularly performed stretching exercises had statistically significant more injuries. Also, for low back injuries, playing more than 6 hours a week was a statistically significant risk factor (Hjelm et al., 2012). In addition, fewer years of tennis experience was associated with a higher risk for upper extremity injuries.

Pluim et al. (Pluim, Loeffen, Clarsen, Bahr, & Verhagen, 2015) prospectively studied 73 elite (national) junior players

Table 2. PRISMA Flow diagram of study selection (up to February 2017).

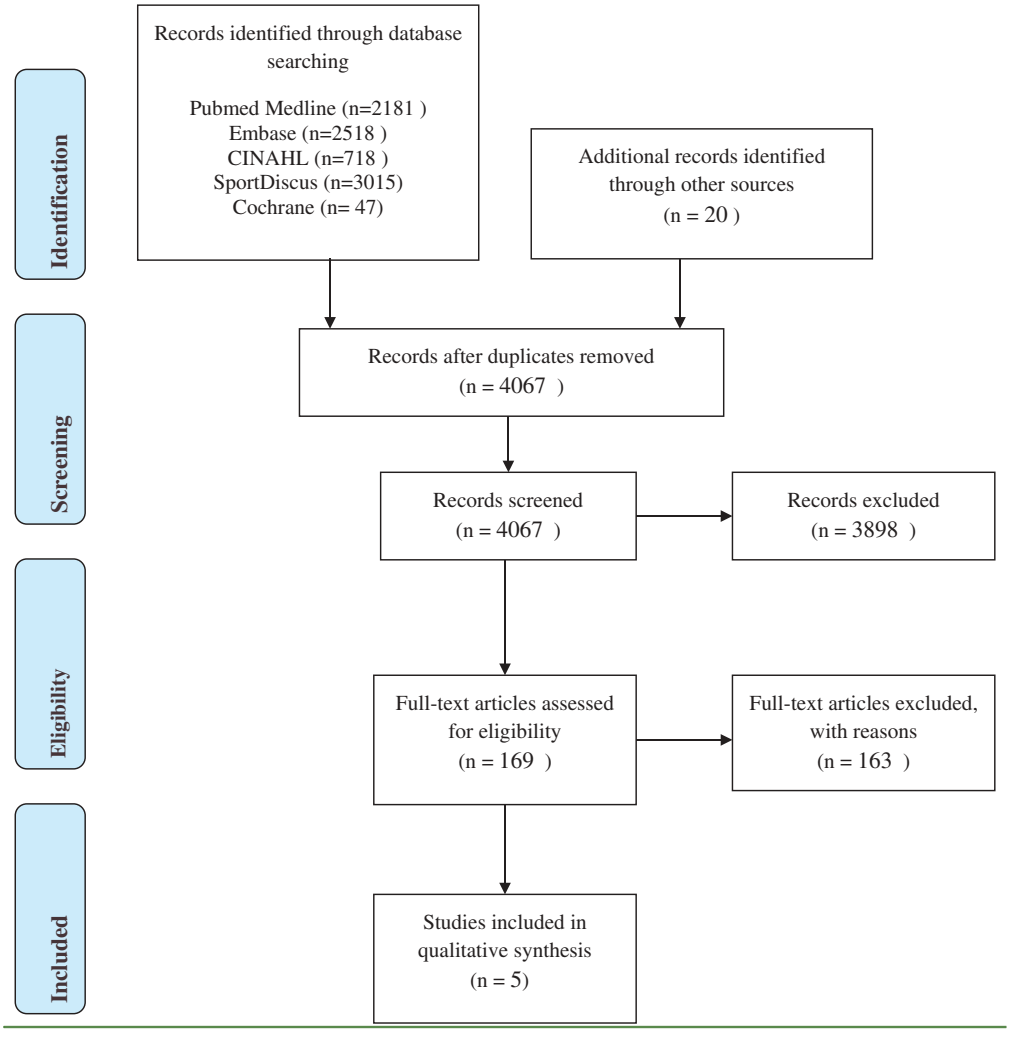

Table 3. Characteristics of included studies for identification of risk factors.

Study*	Study design	Study population	Injury definition	Incidence	Risk factor outcome***	Author's prevention recommendation
Winge et al., 1989, **DK**	Prospective cohort: 6 months	89 elite players; 28F (mean 22.2, 13–43), 61M (mean 28, 14–48)	Injury occurred in connection with tennis training or match, handicapped during play, and/or required special treatment	0.52 inj/player/season; 2.3 inj/1000h	Number of inj/player/1000h training or tennis playing higher in male ($p < .05$)	Proper training of elevating shoulder muscles to prevent UE overuse injuries (38% of all injuries were UE overuse injuries). Increasing shock absorbing capacity for impact force reduction.
Silva et al., 2002, **BR**	Prospective cohort: 1 year	258 players competing in official junior tournaments of Brazilian Tennis Confederation (10–18)	Any consultation and/or treatment given to an athlete during a tournament on-site	6.9 medical appointments/ 1000 games (F < 18 30 MA per 1000 games, M < 18 18.6 MA per 1000games)	n/a	Adequate nutrition and hydration where tournaments are played in tropical circumstances for prevention of illnesses during tennis (cramp).
Hjelm et al., 2012, **SW**	Prospective cohort: 2 year	55 tennis players; 20F, 35M (10–18)	Impossible to participate in regular tennis training or playing matches during at least one occasion (self-reported and examination by principal investigator)	1.5 new inj/1000h; 2.3 total inj/1000h (UE 0.6, LE 1.2, trunk 0.6)	Injured/non-injured (significant risk factor when $p < 0.05$); - General: previous injury ($p = .002$), total play a year h/yr ($p = .032$) - UE: years of tennis play (lesser number of years is higher risk, $p = 0.041$) - LE: stretching before and after tennis play (associated with lower risk, $p = .027$), previous injury ($p = .007$), total play a year ($p = .017$), difference between(non-)dominant side internal rotation of shoulder joint ($p = .015$), difference between (non-) dominant side dorsiflexion of wrist ($p = .023$) - Back: single vs double-play (>6 hrs/week = p.01), previous back-injury ($p = .003$), lateral flexion of neck at dominant side ($p = .017$), racket length normal vs extra length ($p = .028$)	Adequate rehabilitation when injury occurs, including functional performance tests (especially for back injuries). Good stroke technique to prevent UE injuries. General use of stretching exercises may prevent LE injuries.
Pluim et al., 2015, **NL**	Prospective cohort: 32 weeks	73 elite national players; 28F (mean 11.9, 11–14), 45M (mean 12.0, 11–14)	Disorders of musculoskeletal system that affected tennis-participation (self-reported and reviewed by sports physician)	1.2 inj/1000h of tennis	n/a	Off-court training to develop player's endurance
Colberg et al., 2015, **USA**	Prospective cohort: 16 weeks	58 competitive national players; 26F (mean 19.4 ± 1.6), 32M (mean 20.4 ± 1.1)	Musculoskeletal condition with reported time lost (diagnosed by athletic trainer using questionnaires)	1.1 inj/1000 playing-hours	n/a	Education about signs and symptoms of overuse injuries

* Study, year, country. ** mean age, range in years, *** no statistical analysis have been performed on risk factors
DK, Denmark; USA, United States of America; BR, Brazil; SW, Sweden; NL, Netherlands
F, female; M, male
p-value of <0.05 is considered as a significant difference

(45 males, 28 females) with a mean age of 12 years old (range 11-14years) for 32 weeks.

Colberg et al. (Colberg, Aune, Choi, & Fleisig, 2015) prospectively studied 58 competitive (national) players (32 males, 26 females) with a mean age of 20 years old for 16 weeks. Musculoskeletal time loss injuries were analyzed.

3.3 Best evidence synthesis of risk factors

An overview of quality assessment is provided in Table 4. For risk factor identification, best evidence synthesis found: moderate evidence for a previous injury regardless of body location in general (Hjelm et al., 2012), fewer years of tennis experience for the occurrence of upper extremity injuries (Hjelm et al., 2012), reduced lateral flexion of the neck for a back injury (Hjelm et al., 2012), performing pre- and post-stretching and for low back injuries(Hjelm et al., 2012), playing more than 6 hours a week was a statistically significant risk factor (Hjelm et al., 2012).

Limited evidence was found for male gender as a risk factor for tennis injuries (Winge et al., 1989). Additionally, the level of evidence according to best evidence synthesis were approached in a multi factorial model of musculoskeletal injuries(Bahr & Holme, 2003; Meeuwisse et al., 2007), Table 5.

3.4 Study characteristics for prevention studies

No intervention studies on prevention were identified that met the eligibility criteria.

Table 4. Quality and risk of bias assessment.

Subscale	*Item*	Winge (Winge et al., 1989)	Silva (Silva et al., 2002)	Hjelm (Hjelm et al., 2012)	Pluim (Pluim et al., 2015)	Colberg (Colberg et al., 2015)
Reporting	1	1	1	1	1	1
	2	1	1	1	1	1
	3	1	1	1	1	1
	6	1	1	1	1	1
	7	0	0	1	1	1
	9	0	0	1	1	1
External validity	11	1	1	1	1	1
	12	1	1	1	1	1
Bias	16	0	1	1	1	1
	17	1	1	1	1	1
	18	0	0	1	1	1
Confounding	20	1	1	1	1	1
	25	0	1	0	1	0
Power	26	0	0	1	1	0
Score		8	10	13	14	12
Overall level of quality*		fair	good	excellent	excellent	good

1 = explicit study hypothesis/aim/objective; 2 = all primary outcomes described; 3 = characteristics of participants clearly described; 6 = main findings described; 7 = estimates for random variability in data provided; 9 = characteristics of patients lost to follow-up described; 11 = those asked to participate were representative of the entire recruitment population; 12 = those prepared to participate were representative of the entire recruitment population; 13 = staff, places and facilities of treatment were representative of what the majority of patients receive; 16 = "data dredging" was made clear if it occurred; 17 = analysis adjusts for different lengths of follow-up of participants or follow-up is the same for cases and controls; 18 = statistical tests used to assess the main outcomes were appropriate; 20 = the main outcome measures used were accurate; 25 = adequate adjustment for confounding in the analysis; 26 = losses of participants to follow-up taken into account.

* Excellent (13–14); good (10–12); fair (8–9); and poor (≤7)

Table 5. Level of evidence according to the best evidence synthesis.

Evidence	Risk factor	
Moderate	Previous injury for general injuries (Hjelm et al., 2012)	Internal risk factor
	Lower number of years of tennis play for upper extremity injuries (Hjelm et al., 2012)	Internal risk factor
	Less range of motion for lateral neck flexion for a back injury (Hjelm et al., 2012)	Internal risk factor
	Playing >6hrs/week for a back injury (Hjelm et al., 2012)	External risk factor
	Performing pre- and post-stretching (Hjelm et al., 2012)	External risk factor
Limited	Male gender (Winge et al., 1989)	Internal risk factor

3.5 Deviations of the protocol

Prior to definitive quality assessment and based on experience with simultaneous systematic review (SR) conduction, we refrained from using the STROBE statement quality score(von Elm et al., 2007), which was registered on Prospero. Also, re-evaluation of the quality assessment was performed by two reviewers (MM and JBS) to ensure the agreement of quality assessment.

4. Discussion

This is the first systematic review on tennis injuries, which includes a critical study appraisal and best evidence synthesis. The main finding is that there is moderate evidence for a previous injury regardless of body location in general (Hjelm et al., 2012), lower number of years of tennis playing for the occurrence of upper extremity injuries (Hjelm et al., 2012), For low back injuries, previous back injury, playing more than 6 hours a week and low lateral flexion of the back were statistically significant risk factors(Hjelm et al., 2012).

No RCT aiming at prevention of tennis injuries were found.

In absence of a comparable robust systematic review design, our best evidence synthesis cannot be compared with previous reviews on tennis injuries. Since the narrative review of Pluim et al.(Pluim et al., 2006) in 2006, three new prospective risk factor studies were published that met our inclusion criteria(Colberg et al., 2015; Hjelm et al., 2012; Pluim et al., 2015). The multifactorial model of sports injury, described by Meeuwisse et al.(Meeuwisse et al., 2007) and adapted by Bahr et al.(Bahr & Holme, 2003), was used to describe risk factors for the occurrence of musculoskeletal injuries in tennis players. This model divides risk factors into internal, external or an inciting event as risk factor.

Internal risk factors

This review found moderate evidence that previous injuries are a risk factor for general time loss injuries(Hjelm et al., 2012). For upper extremity injuries, years of tennis experience was a risk factor(Hjelm et al., 2012). For lower back injuries, previous back injury and low lateral flexion of the neck were risk factors(Hjelm et al., 2012). Therefore, adequate rehabilitation is required when an injury occurs, especially in preventing back injuries. This finding is consistent with previous research showing that

previous injury was a risk factor in other sports, such as running (Malisoux et al., 2015), badminton(Yung, Chan, Wong, Cheuk, & Fong, 2007), or all sports in children(Difiori et al., 2014).

Limited evidence was found for gender as internal risk factor (Winge et al., 1989). Males had a higher incidence rate for injuries than females during one outdoor tennis season in Denmark(Winge et al., 1989). Recently, an epidemiological study found that female players were more commonly injured than male players(Gescheit et al., 2017).

External risk factors

Moderate evidence was found for regularly performing pre- and post-stretching. Players who regularly performed stretching exercises in general had sustained a lower extremity injury more often than players who did not stretch(Hjelm et al., 2012). A systematic review has already shown that stretching is *not* an effective intervention for reducing sports injuries. However, there are no previous reports showing that stretching might even increase the risk of injury(Jamtvedt et al., 2010; Leppanen, Aaltonen, Parkkari, Heinonen, & Kujala, 2014). Also, for low back injuries, playing more than 6 hours a week was a statistically significant risk factor (Hjelm et al., 2012).

Inciting events as risk factors

No evidence was found for an inciting event as a risk factor. Included studies suggested high workload volume(Hjelm et al., 2012; Pluim et al., 2015; Silva et al., 2002; Winge et al., 1989) and singles play (vs. double play)(Colberg et al., 2015; Winge et al., 1989) as possible risk factors. However, these findings could not be included for best evidence synthesis because of lack of statistical analysis. The explanation for higher injury rate in singles than double players could be that a single's player must cover the whole court where double players share the court and hit fewer balls.

The ultimate purpose of screening for injury risk is to identify athletes at increased risk and mitigate this risk if modifiable factors are identified (Bahr & Holme, 2003). However, an intervention study providing high level evidence to support for the use of screening to reduce injury risk is hard to perform and not yet available(Bahr, 2016). Parents and coaches can be involved in the awareness of injuries for making adjustments in training- and match volume(Pluim et al., 2015).

Limitations

The results of this study should be viewed in light of several limitations. First, the risk factor studies were conducted in specific populations (e.g., junior and elite players). There were no studies that focused on risk factors in recreational tennis players. Therefore, generalizing these findings to recreational players to guide prevention programs should be done with caution. Secondly, injury definition varied between studies. Three studies defined injury as any medical attention given to an athlete(Silva et al., 2002; Winge et al., 1989) where other studies defined an injury when a condition affected participation, which means only time-loss injuries were included, resulting in lower injury rates(Colberg et al., 2015; Hjelm et al., 2012; Pluim et al., 2015). Most studies classified acute and gradual onset of the injury, where acute onset could be linked to an event(Hjelm et al., 2012; Pluim et al., 2015; Winge et al., 1989). The need for uniform terminology and classification of muscle injuries have been described earlier in order to effective communication among medical practitioners(Mueller-Wohlfahrt et al., 2013). In 2009, the International Tennis Federation facilitated a meeting of experts to define medical conditions (injuries and illnesses) that should be recorded in tennis epidemiological studies and criteria for recording the severity and nature of these conditions(Pluim et al., 2009). In addition, Clarsen et al. (Clarsen, Myklebust, & Bahr, 2013) developed a new method for the registration of overuse injuries to avoid underreporting of the chronic ongoing injuries; the Oslo Sports Trauma Research Centre (OSTRC) Overuse Injury Questionnaire. Both limitations could be resolved by using the OSTRC questionnaire in the future. Third, the Downs and Black checklist for risk of bias assessment was not primarily aimed for the evaluation of risk factor studies and therefore we only scored the items applicable for risk factor evaluation. Due to questions regarding the methodological quality of these studies, this review is limited in its ability to draw firm conclusions for level of quality regarding risk factors. A checklist for the evaluation of risk factors needs to be developed for further research studies. Lastly, no studies for testing a prevention program for the occurrence of musculoskeletal tennis injuries were found. Therefore, there is a high need for developing an effective prevention program given the huge global participation in tennis. Prevention strategies can be based on the risk factors found in this study.

Conclusions

The findings of this systematic review can be used to educate players, trainers, and parents about risk factors, and help prevent tennis injuries.

Systematic registration

Registration in the PROSPERO International prospective register of systematic reviews was performed prior study initiation (registration number CRD42015026297).

Disclosure statement

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