ACTIVE & SAFE

Evidence Summary: Tennis

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BC INJURY research and prevention unit

The British Columbia Injury Research and Prevention Unit (BCIRPU) was established by the Ministry of Health and the Minister's Injury Prevention Advisory Committee in August 1997. BCIRPU is housed within the Evidence to Innovation research theme at BC Children's Hospital (BCCH) and supported by the Provincial Health Services Authority (PHSA) and the University of British Columbia (UBC). BCIRPU's vision is *to be a leader in the production and transfer of injury prevention knowledge and the integration of evidence-based injury prevention practices into the daily lives of those at risk, those who care for them, and those with a mandate for public health and safety in British Columbia.*

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UBC BC Children's Hospital Research Institute

Evidence synthesis tool

SPORT:	Tennis	**Target Group:**	Youth, varsity athletes, professional/elite athletes
Injury Mechanisms:	Non-specific mechanisms during play, repetitive/overuse injuries, surface impact, equipment specifications. Most acute injuries occur in the lower extremities, and most chronic injuries occur in the upper extremities. Acute injuries from tennis play have been reported in almost every region of the body (back, abdomen, shoulder, arm, elbow, forearm, wrist/hand, pelvis/hip, thigh/groin, knee, lower leg, calf/achilles, ankle, foot/toes)		

Incidence/Prevalence	**Risk/Protective Factors**	**Interventions**	**Implementation/Evaluation**	**Resources**
The majority of existing incidence and prevalence studies focus on elite level and professional tennis players and are summarized by level of play below. Only one population-based study using a nationally representative study has been conducted. Gaw et al. (2014) reviewed tennis injuries treated in United States emergency departments and found that an estimated 492,002 individuals aged 5-94 presented to US EDs for tennis related injury. Most injuries occurred as the result of a nonspecific mechanism during play (37.9%) and were sustained at a sport or recreation facility (83.4%). Children (age 5 - 8) had a higher average injury rate than adults (over 19). The most commonly injured body regions were the lower extremities (42.2%) followed by the upper extremities (26.7%).[1]	**Age** Studies have shown that the risk of tennis injuries differs by age. A study of elite junior tennis players (age 12-18) demonstrated a significant increase in medical withdrawals as age increased.[1] **Sex** The risk of tennis injuries differs for males and females. The medical withdrawal rate among elite junior tennis players (age 12-18) was significantly higher for boys.[1] However among professional adult tennis players, in one study, women withdrew from competition due to injury significantly more than men[2] whereas in another study, men had a higher injury rate than women (rate ratio, 1.88; 95% CI, 1.17-3.63).[3] **Previous Injury**	Few high-quality intervention studies related to reducing tennis injuries have been conducted. In Pluim et al.'s (2006) systematic review, the authors indicated that they were unable to identify measures proven to prevent tennis injuries as there were no randomised controlled trials available, and limited risk factor studies. Since their review, two experimental studies related to tennis injury prevention that meet the inclusion criteria of this project have been conducted. **Balance Training Program** In a randomized controlled trial of 23 young tennis players, a 6 week, twice weekly balance training program significantly reduced the degree of asymmetry in lower-limb strength (the presence of strength asymmetries in the lower-limbs of youth athletes is considered a risk factor for injury).[2]	Studies on implementation/evaluation of injury prevention interventions for tennis are needed.	**Websites** Children's Hospital of Chicago https://www.luriechildrens.org/en-us/care-services/specialties-services/institute-for-sports-medicine/sports-injury-prevention/Pages/tennis-injury-prevention.asp International Tennis Federation http://www.itftennis.com/scienceandmedicine/injury-clinic/injury-prevention/overview.aspx Kids Health http://kidshealth.org/en/teens/safety-

Junior Competitive Tennis Players (11-18) Four studies reported the incidence of injury in elite junior tennis players.[2-5] Two reported incidence rates ranging from 0.6 - 1.7 per 1000 hours.[2,3] One by athlete exposures (21.5 per 1000 AE),[4] and one by match exposures (15.6 per 1000 ME).[5] **Varsity/Collegiate Level Tennis Players** Lynall et al. (2015) described the epidemiology of national collegiate athletic association men's and women's tennis injuries from 09/10-14/15 and found that injury rates in NCAA men's (1.88/1000 AE) and women's (1.99/1000 AE) were similar overall, and that injury rates were higher during competition than practice.[6] **National and International Level Elite/Professional Adult Tennis Players** Reported injury rates for professional tennis players ranged from 2.3-6.05 injuries per 1000 hours,[7,8] 20.7 per 1000 sets played,[9] and 3.34 per 1000 match exposures.[10] **Elite Wheelchair Tennis Players**	Previous injury is associated with increased risk of sustaining a tennis injury. In one study, previous injury, regardless of body part, was found to be a tennis injury risk factor (OR 8.8, 95% CI 2.1-3.7).[4] When considering lower extremities only, a significant association between preseason complaints and lower extremity injuries was reported (HR 0.29, 95% CI 0.10-0.88).[5] **Flexibility** There is an association between abdominal strains and the presence of hip flexion contractures (OR 6.1, p = 0.006) in elite female tennis players.[6] Limited internal rotation range of motion of the shoulder is associated with shoulder pain history in professional tennis players.[7] **Court Surface** Playing on harder surfaces has been associated with an increased risk of injury. In a study of male and female professional tennis players females were significantly more injured on hard surfaces than on clay.[2] In another study with a similar population where male and female injuries were	**Shoulder Program** In a controlled trial of women's varsity tennis teams, a 5-week, 4 times weekly shoulder strength training program was implemented and significantly increased the eccentric external total work without significant effect on concentric internal total work, concentric internal mean peak force, or eccentric external mean peak force. Therefore potentially decreasing shoulder rotator muscle imbalances and the risk for shoulder injuries to overhead activity athletes.[3] Studies on the cost-effectiveness of tennis injury interventions are needed.		tennis.html OPHEA, The Ontario Physical Education Safety Guidelines http://safety.ophea.net/safety-plan/165/2027 OrthoInfo, American Academy of Orthopaedic Surgeons: http://orthoinfo.aaos.org/topic.cfm?topic=A00186 Pro Tennis Tips (grip size fitting resource) http://protennistips.net/tennis-racquet-grip-size/ Safe Sport http://www.safesport.co.uk/tennissafety.html Sports Medicine Australia http://sma.org.au/resources-advice/sports-fact-sheets/tennis/ Victoria State Government, Better Health Channel https://www.betterhealth.vic.gov.au/health/healthyliving/tenn

Jeon et al. (2010) found a high prevalence of rotator-cuff and acromioclavicular pathology in elite wheelchair tennis players in both shoulders. The most common pathology in the dominant shoulder was acromioclavicular injury and was found in 21 players (63.6%).[11] Pluim et al. conducted a systematic review of tennis injuries in 2006. Unlike this review, they did not asses the methodological quality of included studies. However, their review reported similar results: injury incidence varied from 0.05 to 2.9 injuries per player per year. By hour of play, the review found that incidence varied from 0.04 injuries/1000 hours to 3.0 injuries/1000 hours. Their review identified that there is a high degree of variation in the reported incidence rate of tennis injuries, and that the most frequent site of injuries is the lower extremities, followed by the upper extremities and then the trunk.[12] **Incidence and Prevalence by Injury Type** By injury type, one study showed that elite tennis players	analyzed together, relative incidence showed that medical conditions were significantly higher on hard courts 2.97% (9/303 matches) than on clay 0.90% (3/331; p = 0.04). Further, no medical conditions were reported on grass (0/17) and carpet surfaces (0/68).[8] In contrast, one study found that women were more likely to injure themselves on clay courts compared with hard courts (rate ratio=4.67, 95% CI: 1.41-19.85).[3] **Equipment** Wearing supportive insoles decreased the risk of overuse injuries in tennis (OR=0.13, 95% CI: 0.02-0.79).[5] The patterns of wrist injury (the anatomical site of the lesion) have been associated with how the player grips the racket.[9] A laboratory based experimental study determined that handle grip size affects the grip force which modulates the loading of extensor muscles. The authors indicate that handle grip size therefore appears to be a significant contributing factor in overuse injuries for tennis players, specifically lateral epicondilalgia (tennis elbow).[10] **Playing Time** A study of elite junior tennis			is-preventing-injury

had a 12.9% absolute risk of developing a stress fracture during a two-year period.[13] A systematic review by Stuelcken et al. looked at tennis-related wrist injury and reported incidence rates by athlete exposure ranging from 0.3-0.5 per 1000AE and incident rates by match exposure ranging from 2.06-5.68 per 1000ME.[14]	competitions reported that the medical withdrawal rate increased beyond the fourth match. In the first four matches of a tournament the medical withdrawal rate was 12.7 per 1000, whereas in the fifth match and beyond, it was 26.3 per 1000 ($P < .0001$).[1] In a different study of elite youth tennis players, overuse injuries were significantly associated with total hours of sports participation (OR=7.15, 95% CI: 1.32–38.98).[3] In a study of senior tennis players, the presence of glenohumeral osteoarthritis in the dominant shoulder was greater in former elite tennis players than in sedentary controls (33% in players, 95% CI: 13%-59%, 11 % in controls, 95% CI: 1% to 34%). Prolonged intensive tennis may be a risk factor for mild degenerative articular changes in the dominant shoulder.[11]			
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Review of Sport Injury Burden, Risk Factors and Prevention

Tennis

Incidence and Prevalence

There is a high degree of variation in the reported incidence rate of tennis injuries. (Pluim et al 2006). The most frequent site of injuries is the lower extremities, followed by the upper extremities and then the trunk. According to Pluim et al.'s (2006) review, injury incidence varies from 0.05 to 2.9 injuries per player per year. By hour of play, the review found that incidence varied from 0.04 injuries/1000 hours to 3.0 injuries/1000 hours. The majority of existing incidence and prevalence studies related to tennis injuries focus on elite level and professional tennis players, the results of these studies are summarized by level of play below. Only one population based study using a nationally representative sample has been conducted. Gaw, Chounthirath, and Smith (2014) reviewed tennis injuries treated in United States emergency departments (ED) and found that an estimated 492,002 individuals aged 5-94 presented to United States EDs for tennis related injury. Most injuries occurred as the result of a nonspecific mechanism during play (37.9%) and were sustained at a sport or recreation facility (83.4%). Children (age 5 - 8) had a higher average injury rate than adults (over 19). The most commonly injured body regions were the lower extremities (42.2%), followed by the upper extremities (26.7%).

Junior Competitive Tennis Players (11-18)

Four studies reported the incidence of injury in elite junior tennis players (Heilm, Werner, & Renstrom, 2010; Hutchinson, Laprade, Burnett, Moss & Terpstra, 1995; Jayanthi, O'Boyle, & Durazo-Arvizu; Pluim, Loeffen, Clarsen, Bahr & Verhagen, 2015). Two reported incidence rates ranging from 0.6 - 1.7 per 1000 hours (Hielm et al. 2010; Pluim et al. 2015). One by athlete exposures (AE) (21.5 per 1000 AE) (Hutchinson et al. 1995), and one by match exposures (ME) (15.6 per 1000 ME) (Jayanthi et al., 2009).

Varsity/Collegiate Level Tennis Players

Lynall et al. (2015) described the epidemiology of national collegiate athletic association men's and women's tennis injuries from 2009/10-2014/15 and found that injury rates in NCAA men's (1.88/1000 AE) and women's (1.99/1000 AE) were similar overall, and that injury rates were higher during competition than practice (Lynall, Kerr, Djoko, Pluim, Hainline, & Dompier, 2015).

National and International Level Elite/Professional Adult Tennis Players

Reported injury rates for professional tennis players ranged from 2.3-6.05 injuries per 1000 hours (Maquirrian & Baglione, 2016; Winge, Jorgensen, & Nielson, 1989), 20.7 per 1000 sets played (McCurdie, Smith, Bell & Batt, 2017), and 3.34 per 1000 match exposures (Hartwell, Fong & Colvin, 2016).

Elite Wheelchair Tennis Players

Jeon et al. (2010) found a high prevalence of rotator-cuff and acromioclavicular pathology in elite wheelchair tennis players in both shoulders. The most common pathology in the dominant shoulder was acromioclavicular injury and was found in 21 players (63.6%).

Incidence and Prevalence by Injury Type

By injury type, one study showed that elite tennis players had a 12.9% absolute risk of developing a stress fracture during a two-year period. A systematic review by Stuelcken, Mellifont, Gorman & Sayers (2016) looked at tennis-related wrist injury and reported incidence rates by athlete exposure ranging from 0.3-0.5 per 1000AE and incident rates by match exposure ranging from 2.06-5.68 per 1000ME.

Limitations

The existing incidence and prevalence studies related to tennis injuries are limited in that they primarily focus on elite and professional tennis players. More studies on the incidence and prevalence of recreational tennis injuries are needed. Further, there is a great variation in the reported incidence rate of tennis injuries. It is difficult to make comparisons across studies due to the varying definitions of injury used. The majority of the studies included in this review were retrospective and therefore may be limited by the potential for recall bias.

Risk and Protective Factors

A number of risk and protective factors for tennis injury have been identified in analytical studies and are summarized by modifiable and non-modifiable risk factors below.

Non-modifiable risk factors

Age

Studies have shown that the risk of tennis injuries differs by age. A study of elite junior tennis players (age 12-18) demonstrated a significant increase in medical withdrawals as age increased (Jayanthi, O'Boyle, & Durazo-Arvizu, 2009).

Sex

The risk of tennis injuries differs for males and females. The medical withdrawal rate among elite junior tennis players (age 12-18) was significantly higher for boys (Jayanthi et al., 2009). However among professional adult tennis players, one study demonstrated that women withdrew from competition due to injury significantly more than men (Okholm Kryger et al., 2015) whereas in another study by Hartwell, Fong, and Colvin (2016), men had a higher injury rate than women (rate ratio, 1.88; 95% CI, 1.17-3.63).

Previous Injury

Previous injury is associated with increased risk of sustaining a tennis injury. Hjelm, Werner, and Renstrom (2012) found that previous injury, regardless of body part, increased the odds of sustaining a tennis injury (OR 8.8, 95% CI 2.1-3.7) in junior tennis players. When considering lower extremities only, another study by van Mechelen, Nauta, Pluim and Verhagen (2017), identified a significant association between preseason complaints and lower extremity injuries in youth elite tennis players (HR 0.29, 95% CI 0.10-0.88).[5]

Modifiable Risk Factors

Flexibility

Young, Dakic, Stroia, Nguyen, Harris and Safran (2014) found an association between abdominal strains and the presence of hip flexion contractures (OR 6.1, p = 0.006) in elite female tennis players and Moreno-Perez, Moreside, Barbado, and Vera-Garcia (2015), reported that limited internal rotation range of motion of the shoulder is associated with shoulder pain history in professional tennis players.

Court Surface

Playing on harder surfaces has been associated with an increased risk of injury. In a study of male and female professional tennis players, females were significantly more injured on hard surfaces than on clay (Okholm Kryger et al., 2015). In another study with a similar population, Maquirriain and Baglione (2016) analyzed male and female injuries together and reported that medical conditions were significantly higher in matches played on hard courts 2.97% (9/303 matches) than clay 0.90% (3/331; p = 0.04). Further, no medical conditions were reported on grass (0/17) and carpet surfaces (0/68). In contrast, in Hartwell et al.'s (2016) study women were more likely to injure themselves on clay courts compared with hard courts (rate ratio, 4.67; 95% CI, 1.41-19.85).

Equipment

Equipment can be a risk or a protective factor for tennis injuries. Wearing supportive insoles decreased the risk of overuse injuries in tennis (OR 0.13, 95% CI 0.02-0.79) in van Mechelen et al.'s (2017) study. The patterns of wrist injury (the anatomical site of the lesion) were associated with how the player grips the racket (Tagliafico, Ameri, Michaud, Derchi, Sormani, Martinoli, 2009). In a laboratory based experimental study, Rossi, Vigouroux, Barla, and Berton (2014) determined that handle grip size affects the grip force which modulates the loading of extensor muscles. The authors indicate that handle grip size therefore appears to be a significant contributing factor in overuse injuries for tennis players, specifically lateral epicondilalgia (tennis elbow).

Playing Time

Jayanthi et al.'s (2009) study of elite junior tennis competitions reported that the medical withdrawal rate increased beyond the fourth match. In the first four matches of a tournament the medical withdrawal rate was 12.7 per 1000, whereas in the fifth match and beyond, it was 26.3 per 1000 (P < .0001). In another study of elite youth tennis players, Hartwell et al. (2016) reported that overuse injuries were significantly associated with total hours of sports participation (OR 7.15, 95% CI 1.32–38.98).

In a study of senior tennis players, the presence of glenohumeral osteoarthritis in the dominant shoulder was greater in former elite tennis players than in sedentary controls (33% in players, 95% CI 13%-59%, 11 % in controls, 95% CI 1% to 34%). Prolonged intensive tennis may be a risk factor for mild degenerative articular changes in the dominant shoulder (Maquirriain, Ghisi, & Amato, 2006).

Limitations

The existing studies related to risk and protective factors for tennis injuries are limited by a focus on elite and professional tennis players. More studies are needed to determine if these risk and protective factors are the same for recreational level tennis participation. Several of the studies utilized a cross-sectional study design. More analytical risk factor studies should be conducted so that the above risk factors and the magnitude of their affect can be confirmed.

Opportunities for Prevention: Effective Interventions, Cost-Effectiveness, Implementation and Evaluation

Few high-quality intervention studies related to reducing tennis injuries have been conducted. In Pluim, Staal, Windler, & Jayanthi's (2006) systematic review, the authors indicated that they were unable to identify any measures proven to prevent tennis injuries as there were no randomized controlled trials available, and limited risk factors studies. Since their review, two experimental studies related to tennis injury prevention that meet the inclusion criteria of this project have been conducted.

In a randomized controlled trial of 23 young tennis players, Sannicandro, Cofano, Rosa, and Piccinno (2014) found that a 6 week, twice weekly balance training program significantly reduced the degree of asymmetry in lower-limb strength (the presence of strength asymmetries in the lower-limbs of youth athletes is considered a risk factor for injury).

In a controlled trial of women's varsity tennis teams, a 5-weeek, 4 times weekly shoulder strength training program was implemented and significantly increased the eccentric external total work without significant effect on concentric internal total work, concentric internal mean peak force, or eccentric external mean peak force. Therefore potentially decreasing shoulder rotator muscle imbalances and the risk for shoulder injuries to overhead activity athletes (Niederbracht, Shim, Sloniger, Paternostro-Bayles, & Short, 2008).

High quality randomized controlled trials are needed to identify effective interventions for tennis injury prevention. Studies on the cost-effectiveness and implementation/evaluation of tennis injury interventions are also needed.

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