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A SYSTEMATIC REVIEW COMPARING EPIDEMIOLOGY OF INJURIES IN PADEL, TENNIS AND SQUASH PLAYERS

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Abstract Background: Padel, tennis and squash are racket sports involving repetitive manoeuvres, asymmetrical movements and multiple sprints over short distances. These sports include multiple changes of direction and elements of speed, agility and power. All these factors increase the injury risk in these sports.
Objective: The aim of this systematic review was to investigate the epidemiology of injuries across padel, tennis and squash athletes.
Study Design: This was a systematic review which included EBSCO, CINAHL, MEDLINE, SPORTDiscus, PubMed, and Scopus as the data sources. After risk of bias and quality assessment 11 articles were included for final review.
Results: High prevalence of injuries in padel (85.4%), tennis (39%–46%) and squash (58%) athletes. Injury incidence rate of 3.5–56.6/1000 hours play in tennis and 7.28–14.75/1000 hours of squash exposure. Padel had (44%–49%) tendon and (27%–34%) muscle injuries with most injuries to the elbow (30%–74%). Tennis athletes had (33%–62%) muscle and (11%–38%) ligament injuries with the ankle the most injured (4%–24%). For squash players, muscle (5%–38%) and tendon (23%) injuries were common with most to the ankle (6%–27%). Risk factors across all sports included age, physical demands of the sport and overuse.
Conclusion: Injury epidemiology between the sports was similar with muscular and tendon injuries the most common.

Key words: padel, tennis, squash, musculoskeletal injury

Introduction

Padel is described as a blend between tennis and squash involving repeated changes of direction, rapid acceleration, and deceleration over short distances requiring speed, agility and power (Demeco et al., 2022; Jones

et al., 2018; Nhan et al., 2018). All three sports involve repetitive manoeuvres placing stress on the extremities with the recurring overhead motion placing repetitive rotational stress on the shoulder (Demeco et al., 2022; Nhan et al., 2018; Vasenina, et al., 2022). These sports are asymmetrical causing imbalanced laterality resulting in muscle strength disparities and flexibility differences increasing injury risk (Kamalden et al., 2021; Sánchez-Alcaraz et al., 2021). Injuries in sport are reported as incidence and the cause of injury reported as mechanism of injury.

Incidence refers to the number of injuries during a specific period whereas prevalence refers to the number of existing injuries at one point in time (Tenny & Boktor, 2023). Sports injuries are reported as rate per 1000 hours and can include athlete exposures (potential exposure to injury), risk, match or practice hours (Balazs et al., 2015; Tenny & Boktor, 2023). Mechanism of injury is used to describe how trauma affects the structures of the body usually through an energy transfer which can be direct or indirect and non-modifiable (age or gender) or modifiable (physical conditioning or equipment) (Bahr & Holme, 2003; Toney-Butler & Varacallo, 2023).

Reported injury incidence between the three sports is similar – 8.4 injuries/1000 hours play time in padel (elite and amateur athletes), 8.2 injuries/1000 hours of play in tennis (elite athletes) and 5 injuries/1000 hours reported in squash (García–Fernández et al., 2019; Moreno-Pérez et al., 2019; Finch & Eime, 2001). Amateur athletes have a decreased volume of training and match play presenting with injuries related to overuse and muscle asymmetry compared to elite athletes (Kamalden et al., 2021). The areas of the body commonly injured were the lower limb (ankle and knee), and lower back with muscular and tendon injuries the most prevalent (Nhan et al., 2018; Sánchez-Alcaraz & Courel-Ibáñez, 2022; Williams & Hebron, 2018; Vasenina et al., 2022). In padel athletes the elbow, shoulder, ankle and knee were the areas most injured compared to tennis athletes with lower back, ankle and knee injuries and squash athletes with ankle and knee injuries (Dahmen et al., 2023; Sankaravel et al., 2017; Vasenina et al., 2022).

The aim of this systematic review was to assess existing literature regarding the epidemiology and types of injuries found in padel, tennis and squash athletes as no research has compared these factors in these sports. By identifying common risk factors and types of injuries across each of these sports, sports specific injury prevention programmes can be developed to reduce injuries, injury burden and time lost due to injury.

Methods

Design

The systematic review followed the PRISMA guidelines shown in Figure 1 (Page et al., 2020).

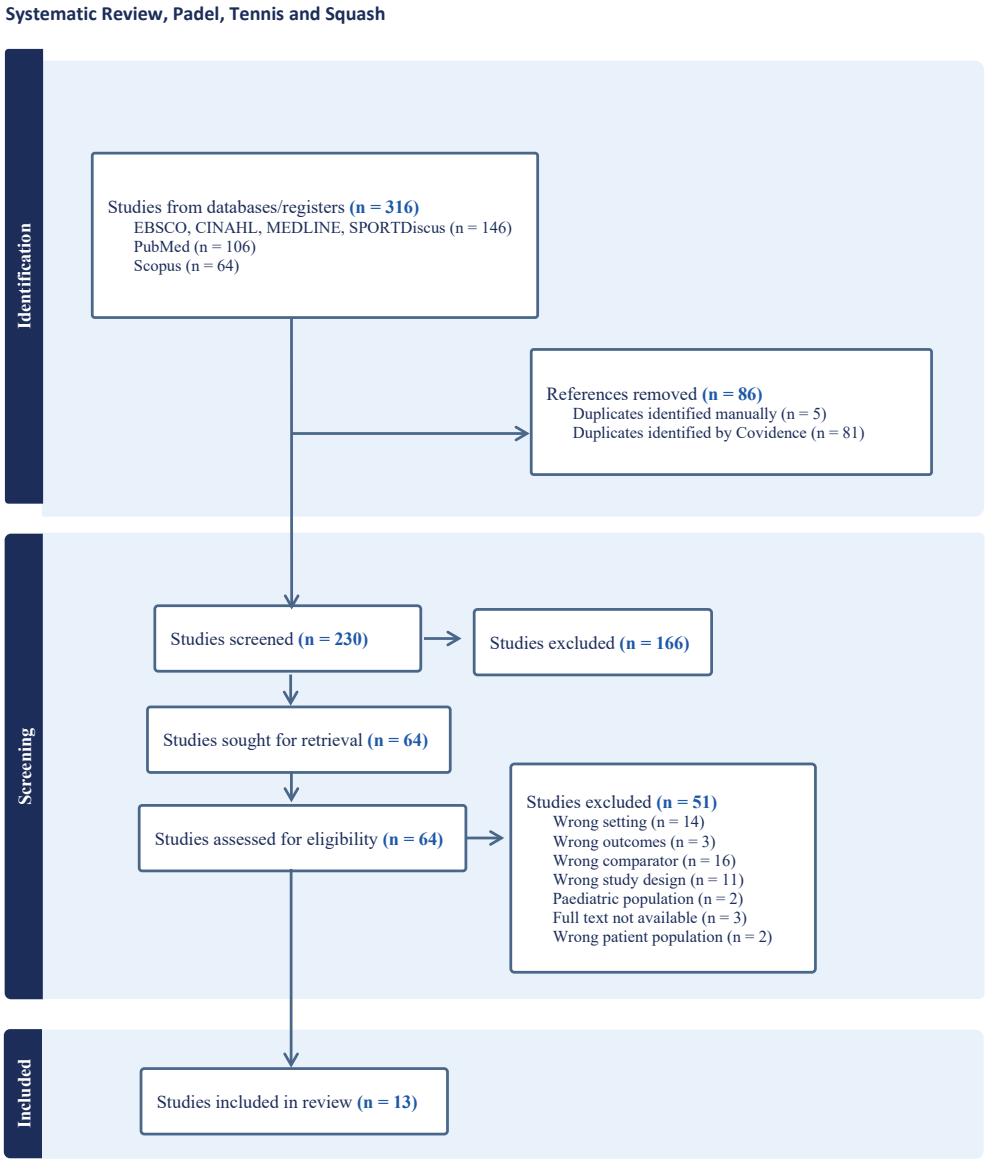

Figure 1. PRISMA flowchart of search procedure.

Data search and sources

Search strategies used the keywords 'musculoskeletal injury', 'epidemiology', 'aetiology', 'prevalence', 'padel', 'tennis' and 'squash'. Two independent reviewers evaluated the titles and abstracts of identified articles. The databases searched included EBSCO, CINAHL, MEDLINE, SPORTDiscus, PubMed, and Scopus, performed between 29 April and 10 May 2024. Filters included: Humans, English, Academic Journal, Full Text, Adolescent and Adult. All keyword search terms were combined with 'AND' and 'OR'.

Eligibility criteria

The eligibility criteria were structured according to the PICOS framework, specifically adapted for this review (Eriksen & Frandsen, 2018). The criteria included:

- Population (P) consisted of athletes playing padel, tennis or squash, were at least eight years old or above and any gender. All athletes included in the studies had given informed consent for the data collected.
- Intervention (I) included studies reporting any injury suffered while playing padel, tennis or squash.
- Context or comparators (C) were defined as studies comparing injuries in athletes playing padel, tennis or squash to assess similarities and differences in aetiology, risk factors and types of injury between the three sports.
- Outcomes (O) analysed were those that assessed and identified the type of injuries, aetiology and risk factors causing injury in padel, tennis and squash athletes.
- Included studies (S) were cross-sectional, cohort studies and one case study.
- Exclusion criteria included unpublished articles, review articles, studies where the population included sports other than padel, tennis or squash. Studies with incompatible comparators, population, study designs were also excluded.

Study selection and data extraction

Two researchers independently reviewed the titles and abstracts of the retrieved citations with duplicate articles eliminated. Citations were downloaded from the databases (RIS text format) and articles were imported into Covidence based on the inclusion criteria (Covidence systematic review software, 2024). Covidence is a web-based systematic review software used to synthesise literature for systematic reviews with full-text references uploaded and screened independently (Covidence systematic review software, 2024). Disagreements regarding article inclusion and exclusion were resolved by discussion between reviewers. Two researchers independently extracted the characteristics and results of the interventions from the included publications.

Quality assessment

The Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Prevalence Studies (2020) was used to assess the quality of the articles for cohort or case series study design (Table 1) **(**Appendix 1). This tool is used to appraise studies investigating prevalence and incidence in research and assesses methodological quality (Migliavaca et al., 2020). The checklist has nine items requiring an answer of 'yes, 'no', 'unclear', or 'not applicable'. While there is no scoring for these items, an overall appraisal of quality is given to 'include', 'exclude' or 'seek further information'. There were eight articles appraised using the JBI checklist – seven were classified as cohort and one as a case study.

The remaining five articles utilised a cross-sectional study design where the Appraisal Tool for Cross-Sectional Studies (AXIS Tool) (2016) was used (Table 2) (Appendix 2). This tool consists of 20 items requiring a 'yes', 'no' or

'don't know' answer (Downes et al., 2016). There is no numerical rating for the 20 items, and the article appraisal is subjective (Munn et al., 2020).

Table 1. JBI Critical Appraisal Tool used for cohort studies

Article	Kaiser et al., 2021	Abadi et al., 2021	Dakic et al., 2018	Lynall et al., 2016	Castillo-Lozano, 2017	Muñoz et al., 2022	Horobeanu et al., 2019	Horsley et al., 2020
1. Appropriate sample frame?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2. Participants sampled appropriately?	Not reported	Not reported	Not reported	Yes	Not reported	Not reported	Not reported	Not reported
3. Adequate sample size?	Yes	Yes	Yes	Unclear	Yes	Yes	Unclear	Yes
4. Subjects and setting described sufficiently?	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
5. Data analysis sufficient sample coverage?	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	Yes
6. Valid methods for condition identification?	Unclear	Yes	Yes	Yes	Yes	Unclear	Yes	Yes
7. Condition measured standard and reliable for participants?	Unclear	Unclear	Yes	Yes	Yes	Yes	Yes	Yes
8. Statistical analysis appropriate?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
9. Adequate response rate?	Not reported	Not reported	Not reported	Yes	Not reported	Not reported	Yes	Not reported
Overall appraisal	Include	Include	Include	Exclude	Include	Include	Include	Include

Table 2. AXIS for cross-sectional studies

Article	Acquaye et al., 2020	Minghelli & Cadete, 2019	Rice et al., 2022	Castillo-Lozano & Casuso-Holgado, 2017	Castillo-Lozano & Casuso-Holgado, 2015
1. Aims/objectives clear?	Yes	Yes	Yes	Yes	Yes
2. Study design aligned to aim(s)?	Yes	Yes	Yes	Yes	Yes
3. Sample size justified?	Yes	Not reported	Not reported	Not reported	Not reported
4. Target population clearly defined?	Yes	Yes	Yes	Yes	Yes
5. Sample frame appropriate representation target population?	Yes	Yes	Yes	Yes	No
6. Participants representative of target population?	Yes	Yes	Yes	Yes	Yes
7. Measures to address non-responders?	Not reported	Not reported	Not reported	Not reported	Not reported
8. Risk factor and outcomes appropriate to aims?	Yes	Yes	Yes	Yes	Yes
9. Risk factors and outcomes measured using published instruments?	Yes	Yes	Yes	Not reported	Yes
10. Clear how statistical significance and/or precision estimates determined?	No	Yes	Yes	Yes	Yes
11. Methods sufficiently described to enable repeatability?	Yes	Yes	Yes	Yes	Yes
12. Basic data adequately described?	Yes	Yes	Yes	Yes	Yes
13. Response rates raise concerns about nonresponse bias?	No	No	No	No	Yes

14. Information about non-responders described?	No	Not reported	Not reported	Not reported	Not reported
15. Results internally consistent?	Yes	Yes	Yes	Yes	Yes
16. Results for analyses described in methods, presented?	Yes	Yes	Yes	Yes	Yes
17. Authors' discussions and conclusions justified by results?	Yes	Yes	Yes	Yes	Yes
18. Limitations discussed?	No	Yes	Yes	Yes	Yes
19. Funding sources/conflicts of interest affecting interpretation of results?	No	No	Yes	No	No
20. Ethical approval/consent attained?	Yes	Yes	Yes	Yes	Yes
Overall appraisal	Exclude	Include	Include	Include	Include

Results

Data search and study selection

The database search of EBSCO, CINAHL, MEDLINE, SPORTDiscus, PubMed, and Scopus produced a total of 316 studies. Eighty-six duplicates were identified and removed. Two hundred and thirty studies were screened according to the title and abstract with 166 articles removed. The remaining 64 articles were read and assessed for eligibility with 51 studies not meeting eligibility criteria. Thirteen studies met the criteria and objectives for this review (Figure 1).

Risk of bias and quality assessment

Thirteen articles included in the final review were appraised by one reviewer using the AXIS (for cross-sectional studies) and JBI critical appraisal tool (for cohort studies). Following the quality assessment two further studies were excluded resulting in 11 articles for final review (Tables 1 and 2). The main issues identified were failure to report characteristics of participants, insufficient information to determine statistical significance and failure to report limitations.

Study characteristics

Key details from the studies included in the systematic review are presented in Table 3.

Table 3. Included studies

Study	Study characteristics	Study design	Population description/Sample	Participant's Age (Years)
Muñoz et al., 2022	Incidence upper body injuries	Cohort -questionnaire	950 amateur padel players (803 male, 147 female)	Men 29.99 ±10.80 Women 33.37 ±13.03
Castillo-Lozano & Casuso-Holgado, 2015	Comparison musculoskeletal injury	Cross sectional – questionnaire	60 junior and senior padel players (54 male, 6 female)	14–67
Castillo-Lozano & Casuso-Holgado, 2017	Incidence musculoskeletal sport injuries	Cross sectional	113 recreational padel players (54 male, 59 female)	38.38 ±16.76
Castillo-Lozano, 2017	Epidemiology and prevention strategies for musculoskeletal injuries	Cohort – retrospective data	131 senior padel players (107 male, 24 female)	50–66
Horsley et al., 2020	Epidemiology of injuries	Cohort – retrospective data	67 elite squash players (45 male, 22 female)	18–35
Horobeanu et al., 2019	Prevalence musculoskeletal injuries	Cohort – prospective	21 male adolescent elite squash players	14.5 ±1.7

Kaiser et al., 2021	Acute tennis injuries	Case series – retrospective data	449 recreational tennis players. (301 male, 148 female)	8–84
Rice et al., 2022	Age and gender differences, injuries and risk factors	Cross sectional	237 elite junior and professional tennis players (111 male, 126 female)	9–27
Abadi et al., 2021	Incidence rate musculoskeletal injuries	Cohort – prospective	161 tennis players professional tournaments (90 male, 71 female)	22.0 ±4.1
Minghelli & Cadete, 2019	Epidemiology musculoskeletal injuries, risk factors	Cross sectional – questionnaire	218 tennis athletes (156 male, 62 female)	9–72
Dakic et al., 2018	Musculoskeletal injury profiles	Cohort	52 female professional players	24.8 ±4.85

Data organisation

For the purposes of this review the studies were grouped into the three sports (padel, squash and tennis), according to main results and conclusions (Tables 4 to 6).

Table 4. Summary of padel related studies

First author	Main Results	Conclusion
Muñoz et al., 2022	Men ↑ muscle (42%), ligament (56%) shoulder; tendon (49%) elbow. Women ↑ muscle – shoulder (59%), arm (18%), ligament (67%) elbow, bone (50%) wrist and elbow (25%). ↑ racket weight ≥ 350g, playing > six hours/week but ↓ practicing > five years.	Tendon injuries most common – shoulder and elbow Injury risk: racket characteristics, volume weekly practice, experience and gender
Castillo-Lozano & Casuso-Holgado, 2015	Senior group: elbow. ↑ injuries – longer career. Main injury: lateral epicondylitis (37% senior, 10% junior. Other: shoulder (10% senior, 7% junior) knee (20% senior, 10% junior) and lower back (13% senior, 23% junior).	Most injured: upper and lower limbs. Elbow, lower back and knee.
Castillo-Lozano & Casuso-Holgado, 2017	85% reported injuries. Joint – elbow (74%), lower back (20%) and knee (15%). Females: shoulder (17%), lower back (20%) and calf (22%) Males: lower back (17%), knee (17%) and shoulder (9%).	Injured regions: elbow, lower back and knee. Lateral epicondylitis – improper technique. Musculoskeletal injuries ↑ females.
Castillo-Lozano, 2017	Main injuries: elbow (29%), lower back (28%), knee (23%), ankle (22%) and shoulder (21%).	Acute injuries ↑ lower extremity. Chronic overuse: lateral epicondylitis, shoulder and low back pain. Main risk factor: age.

↑ – increase/increased,
↓ – decrease/decreased

Table 5. Summary of squash related studies

First author	**Main Results**	**Conclusion**
Horsley et al., 2020	592 injuries, average 9/athlete and 0.46 injuries/athlete/month. Most injured: lower limbs (77%), ankle/heel (21%), thigh (13%), knee (11%), hip/groin (10%), buttock (8%), lower leg (8%), and foot (8%). Most injuries: soft tissue	Professional players ↑ lower limb injuries. Mainly ankle and heel, soft tissue
Horobeanu et al., 2019	100% one/more injuries. Overall incidence 15/1000 hours training, average 10/athlete over 6-year period. Most injuries lower limb (58%) thigh, knee, lumbar area and hand.	Pre-mature players ↑ risk growth-related injuries. Lower limb most injured, trunk and upper limbs. Knee and thigh (25%), foot and ankle (14%), lower leg (9%) and hip/groin (2%).

↑ – increase/increased

Table 6. Summary of tennis related studies

First author	Main Results	Conclusion
Kaiser et al., 2021	467 injuries. ↑ prevalence summer. Lower limb (59%), upper limb (30%), head and trunk (11%). Main cause: twist of joint/fall. Contusion/strains (49%).	Acute injuries recreational players differ from elite and junior players, with ↑ fractures. Main cause: falls/twists.
Rice et al., 2022	Adolescent ↑ trunk injuries (39%). Adults ↑ lower limb injuries (54.2%). Lower limb injuries elite athletes (acute and overuse), ↑ demands. All elite athletes ↑ failed trunk stability tests.	Impairments trunk stability, lower limb flexibility, and hip rotation ROM affect health and performance. Elite athletes may benefit from off court programming addressing impairments.
Abadi et al., 2021	IR high 31/1000 PH. Most: acute (61%), trunk (39%), lower limb (33%), upper limb (25%). Muscle (61%), ligament (17%), tendinopathy/bursitis (14%) and muscle spasm (8%). Risk factors: ↑ body height, skill level, previous injury, and WBGT zone.	Incidence musculoskeletal injuries professional players high. Risk factors: body height, skill level, previous injury, and WBGT zone.
Minghelli & Cadete, 2019	High prevalence (39% in 12-months and 35% in 6-months). Injury rates 3.5/1000 hours training. Most injured: ankle (20%), wrist (16%), lumbar spine (13%) and knee (13%). Joint injuries (30%), tendinopathy (22%) and muscle (15%). 77% during training. Clay surface ↑ injury. ↑ frequency and duration training correlated to ↑ injury.	High prevalence injuries. Most common: joint injuries and tendinopathy. Most affected: ankle, wrist, lumbar spine and knee. Main mechanism: service action.
Dakic et al., 2018	216 injuries. Overall IR 57 /1000hours of MP. Average 4 injuries/ season. Thigh (17%), shoulder/clavicle (9%), knee (8%) and ankle (8%). 50% of injuries – muscle/tendon, (38%) joints and (5%) bone.	Injury IR ↑ than previously reported. Lower limb twice as common. Thigh injuries highest IR. Shoulder and knee injuries ↑ competition time loss. Match volume associated with number injuries and competition time loss.

↑ – increase/increased; IR ROM, internal rotation range of motion; IR, incidence rate; PH, player hours; WGBT, wet bulb globe temperature; MP, match play

Incidence and prevalence of injury

All studies in this review investigated either the incidence or prevalence of injuries of padel, tennis and squash athletes. Included studies calculated injury incidence rate differently making it difficult to compare results between studies until this calculation is standardised. The injury prevalence, incidence, type and body area for padel, tennis and squash are presented in Table 7.

Table 7. Injury characteristics

		Padel	Tennis	Squash
Injury Prevalence and incidence	Injury prevalence (%)	85.4% [1]	39.4%–46% [2,3]	58%*[4]
	Incidence rate/1000 hours	Not reported	3.5 TH [2]	7.3 –14.8* SE [4,7]
			30.8 PH [5]	
			56.6 MP [6]	
	Injury/athlete/12 months	Not reported	0.4 – 4 [2,6]	1.7* – 5.5 [4,7]
Type of injury	Tendon	44%–49%[8]	14%–22%[2,5]	23%[7]
	Muscle	29%–34%[8]	33%–62%[2,5]	5%–38%[4,7]
	Ligament	10%–20%[8]	11%–38%[6,9]	10%[7]
	Bone	7%[8]	5%–12%[6,9]	16%[7]

Area of body	**Upper extremity**		**11%–30%**[3,9]	**9%4**
	Shoulder	13%–21%[1,10]	8%–10%[2,9]	2%–4%[4,7]
	Elbow	30% –74%[1,10]	3%–7% [2, 6]	1%[4]
	Wrist	3%–12%[8,10]	7%–18%[6,9]	2%[4]
	Lower Back	13%–28%[10,11]	7%–13%[2,6]	7%[4]
	Lower extremity		**20%–59%**[3,9]	**50%–76%4,7**
	Knee	15%–23%[1,10]	8%–19%[6,9]	11%–12%[4,7]
	Ankle	7%–10%[10,11]	4%–24%[6,9]	14%–27%[4,7]
	Calf	14–22%[1,10]	5%–7%[2,6]	8%–9%[4,7]

* Junior athletes, PH - player hours, TH – training hours, MP – match play, SE – squash exposure

[1] Castillo-Lozano & Casuso-Holgado, 2017, [2] Minghelli & Cadete, 2019, [3] Rice et al., 2022, [4] Horobeanu et al., 2019, [5] Abadi et al., 2021, [6] Dakic et al., 2018, [7] Horsley et al., 2020, [8] Muñoz et al., 2022, [9] Kaiser et al., 2021, [10] Castillo-Lozano, 2017, [11] Castillo-Lozano & Casuso-Holgado, 2015

Risk factors and mechanism of injury

Risk factors for injury in padel athletes included racket weight (> 350g), composition and number of over grips all of which differed between athletes (Muñoz et al., 2022). Other risk factors included volume of practice, experience levels (> six hours/week and < five years' experience), athletes age, body mass index (BMI) and laterality (Castillo--Lozano, 2017, Muñoz et al., 2022). Lack of technique was related to elbow injuries and repeated overhead shots caused shoulder injuries (Castillo-Lozano & Casuso-Holgado, 2015). Several risk factors were identified in tennis athletes including age, training > three times per week, experience levels, gender, court surface (clay surface increases risk), overuse, height, previous injury, shoe type and if players warmed up (Kaiser et al., 2021; Abadi et al., 2021; Minghelli & Cadete, 2019; Dakic et al., 2018). The main risk factor for ankle injuries in tennis is sudden multidirectional movement changes within the game (Kaiser et al., 2021). Contributing factors for squash injuries have been reported as: the physical demands of the sport, age, the confined area of the court and the proximity of players to each other (Horsley et al., 2020; Horobeanu et al., 2019).

Discussion

Incidence and prevalence of injury

The included studies revealed that 85.4% of padel athletes had an injury which is consistent with the literature reporting 40%-95% prevalence (Castillo-Lozano & Casuso-Holgado, 2017; Dahmen et al., 2023). The prevalence in tennis athletes was 39%-46% which is lower than the 67% reported by Fu et al. (2018), Rice et al., (2022), and Minghelli and Cadete, (2019). Research by Finch and Eime, (2001) reported prevalence of squash injuries as 59%, comparable to the 58% of squash athletes (junior) in this review (Horsley et al., 2020; Horobeanu et al., 2019). These injury rates vary between the studies and sports due to the variety of data collection methods and difference in injury definition between the studies. Recall bias may have impacted the results from the studies that utilised questionnaire and retrospective data collection (Althubaiti, 2016).

The incidence in tennis injury in this review is between 3.49/1000 hours training to 56.6/1000 hours match play compared to the 8.2/1000 hours of play in tennis previously reported (Minghelli & Cadete, 2019; Dakic et al., 2018; Moreno-Pérez et al., 2019). Previous research described the injury incidence in padel ranging between 2.8 to 8.4 injuries/1000 hours and was not reported per 1000 hours in this study (García-Fernández et al., 2019; Sánchez-

Alcaraz & Courel–Ibáñez, 2022). The injury incidence in squash has previously been stated as 5/1000 squash sessions compared to the 7.28–14.75/1000 hours squash exposure in this review (Horobeanu et al., 2019: Horsley et al., 2020; Finch & Eime, 2001). As the results were not standardised according to injury rates per 1000 hours of play time, a direct comparison between the studies and existing literature is not possible. Standardisation of injury rates should be considered as injuries per/1000 hours sport exposure and include practice and match time (Balazs et al., 2015). Certain incidence rates are reported only as match hours and exclude practice hours or vice versa. Any time spent playing a sport is exposing an athlete to potential injury.

Type of injury

Padel athletes had 44%–49% tendon and 29%–34% muscle injuries (Table 7), comparable to literature reporting tendon (40.4%) and muscle (30.7%) injuries as the most common (Dahmen et al., 2023; Demeco et al., 2022; García–Giménez et al., 2022). The areas of the body most injured were the elbow (30%–74%), shoulder (13%–21%), knee (10%–23%) and calf (14%–22%). Research examining professional and amateur padel athletes reported the majority (53,1%) of injuries to the lower limb (ankle sprains) and 37.5% to the upper limb (elbow and shoulder) (Dahmen et al., 2023; Demeco et al., 2022; García–Giménez et al., 2022). Research by García-Fernández et al., (2019) found the areas most injured were the elbow (20.5%), foot (11.5%) and knee (10.8%) compared to Pérez et al. (2023) whose results showed ankle, hip/groin (both 15.6%), knee (12.5%) and shoulder (9.4%).

Tennis athletes sustained muscle (33%–62%) and ligament (11%–38%) injuries (Table 7), consistent with previous findings that identified ligament (36.4%) and muscle (31.6%) as the structures most affected (Krueckel et al., 2024). The areas of the body most affected (Table 8) were the ankle (4%–24%), knee (8%–19%), wrist (7%–18%) and lower back (7%–15%) similar to Krueckel et al., (2024) reporting the ankle (29.8%), thigh (13.1%), shoulder (12.5%) and lower back (8.2%).

Muscle (5%–38%) and tendon (23%) were the most common structures injured in squash athletes (Table 7) which compares to findings by Sankaravel et al., (2017), reporting 83.3% musculoskeletal (sprains and strains), and 34% sprains and strains described by Nhan et al., (2018). The areas of the body most injured from the included studies were to the lower extremities (50%–75%), the ankle (6%–27%), knee (11%–12%) and calf (8%–9%) (Horsley et al., 2020; Horobeanu et al., 2019). Previous research found the lower extremities (35%), head and neck (33.7%), wrist and hand (31.7%), ankle (26.7%) and shoulder (25%) were the most affected (Sankaravel et al., 2017, Nhan et al., 2018).

Risk factors and mechanism of injury

Risk factors for injury identified for all three sports include age, physical demands of the sport and overuse (Horsley et al., 2020; Horobeanu et al., 2019; Muñoz et al., 2022; Kaiser et al., 2021; Abadi et al., 2021). For padel additional risk factors included the racket weight (> 350g), body mass index (BMI), lack of technique, volume of practice, experience levels and game characteristics such as the unpredictable trajectory and ball velocity (Muñoz et al., 2022; Castillo-Lozano & Casuso-Holgado, 2015; Castillo-Lozano, 2017; Demeco et al., 2022). Research suggests the size of the padel court and faster pace of play increased neuromuscular fatigue and impaired motor control, influencing injury rates (Perez et al., 2023). Rapid increases in acute load, accumulative load and higher competitive volume in a short time also increased injury risk (Sánchez-Alcaraz & Courel-Ibáñez, 2022; Perez et al., 2023).

Additional risk factors in tennis included player height, court surface, previous injury, shoe type, if players warmed up and multidirectional movement changes (Kaiser et al., 2021; Abadi et al., 2021; Minghelli & Cadete, 2019;

Dakic et al., 2018). Other risk factors identified include sudden changes of direction, acceleration and deceleration, and the amount of high velocity shots per session (Moreno-Pérez et al., 2019; Vasenina et al., 2022). High training volume, competition load and mechanical overload increases risk for overuse injuries (Williams & Hebron, 2018; Vasenina et al., 2022, Kekelekis et al., 2020). Muscle asymmetry decreased flexibility (lower back and hamstrings) and previous injury have also been identified as risk factors in tennis (Williams & Hebron, 2018; Vasenina et al., 2022, Kekelekis et al., 2020).

Contributing factors for squash injuries include the physical demands of the sport, the confined area of the court and the proximity of the players to each other (Horsley et al., 2020). These are consistent with the existing literature. Additional risk factors include overuse and the squash ball reaching up to 230 km/hr (Nhan et al., 2018; Sankaravel et al., 2017).

Key findings, considerations and limitations

Tennis, squash and padel have a high prevalence of musculoskeletal injuries with variations noted between the sports. Padel athletes mainly suffered from tendon injuries compared to muscular injuries in tennis and squash athletes. The elbow was the joint most affected in padel compared to the ankles and knees in tennis and squash. As the reported incidence rates were not standardised it is not possible to directly compare the cases/1000 hours of play time. Future research needs to explore the incidence reporting rates in a more standardised manner.

Conclusions and recommendations

There is a high prevalence of injuries in padel (85.4%), tennis (39–46%) and squash (58%) athletes. In all three sports the musculoskeletal structures (muscles, tendons and ligaments) were the most injured with the area of injury differing slightly in each sport. Padel athletes mainly had tendon injuries with the elbow, shoulder, knee and calf most affected. Tennis and squash athletes had more muscular injuries with the knee and ankle commonly injured in both sports. Additionally, tennis athletes had wrist and lower back injuries while squash athletes had calf injuries. Risk factors for injury depend on the characteristics of each sport including the surface and equipment used, volume of training or matches, experience levels and overuse. We recommend that injury incidence needs to be standardised to directly compare between sports as injury/1000 hours sport exposure. Practically these results can be used by coaches, players and physical trainers to improve the physical requirements of athletes and reduce modifiable risk factors such as physical strength and conditioning, training volume and equipment specific to each sport. The high incidence rates in padel, tennis and squash require further investigation especially at amateur level. Lastly, further research into injury risk in padel, tennis and squash athletes need to be conducted to identify those factors that are modifiable.

Appendix 1:

JBI Critical Appraisal Checklist for studies reporting prevalence data

Reviewer _____ Date_____

Author_____ Year_____ Record Number_____

	Yes	No	Unclear	Not applicable
Was the sample frame appropriate to address the target population?	□	□	□	□
Were study participants sampled in an appropriate way?	□	□	□	□
Was the sample size adequate?	□	□	□	□
Were the study subjects and the setting described in detail?	□	□	□	□
Was the data analysis conducted with sufficient coverage of the identified sample?	□	□	□	□
Were valid methods used for the identification of the condition?	□	□	□	□
Was the condition measured in a standard, reliable way for all participants?	□	□	□	□
Was there appropriate statistical analysis?	□	□	□	□
Was the response rate adequate, and if not, was the low response rate managed appropriately?	□	□	□	□

Overall appraisal: Include □ Exclude □ Seek further info □

Comments (Including reason for exclusion)

_____

_____

Appendix 2:

Appraisal of Cross-sectional Studies

	Question	Yes	No	Don't know/ Comment
Introduction				
1	Were the aims/objectives of the study clear?			
Methods				
2	Was the study design appropriate for the stated aim(s)?			
3	Was the sample size justified?			
4	Was the target/reference population clearly defined? (Is it clear who the research was about?)			
5	Was the sample frame taken from an appropriate population base so that it closely represented the target/reference population under investigation?			
6	Was the selection process likely to select subjects/participants that were representative of the target/reference population under investigation?			
7	Were measures undertaken to address and categorise non-responders?			
8	Were the risk factor and outcome variables measured appropriate to the aims of the study?			
9	Were the risk factor and outcome variables measured correctly using instruments/measurements that had been trialled, piloted or published previously?			
10	Is it clear what was used to determined statistical significance and/or precision estimates? (e.g. p-values, confidence intervals)			
11	Were the methods (including statistical methods) sufficiently described to enable them to be repeated?			
Results				
12	Were the basic data adequately described?			
13	Does the response rate raise concerns about non-response bias?			
14	If appropriate, was information about non-responders described?			
15	Were the results internally consistent?			
16	Were the results presented for all the analyses described in the methods?			
Discussion				
17	Were the authors' discussions and conclusions justified by the results?			
18	Were the limitations of the study discussed?			
Other				
19	Were there any funding sources or conflicts of interest that may affect the authors' interpretation of the results?			
20	Was ethical approval or consent of participants attained?			

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