

Epidemiology of sports injuries in basketball: integrative systematic review

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To cite: Andreoli CV, Chiaramonti BC, Biruel E, *et al*. Epidemiology of sports injuries in basketball: integrative systematic review. *BMJ Open Sport & Exercise Medicine* 2018;**4**:e000468. doi:10.1136/bmjsem-2018-000468

Accepted 20 November 2018

ABSTRACT

Introduction Basketball is a contact sport with complex movements that include jumps, turns and changes in direction, which cause frequent musculoskeletal injuries in all regions of the body.

Objective This is an integrative systematic review of the epidemiology of musculoskeletal injuries in basketball.

Methods This is an integrative review based on the following sources of information: PubMed/MEDLINE, Embase, LILACS, BBO-Biblioteca Brasileira de Odontologia, IBECs-Índice Bibliográfico Espanhol em Ciências da Saúde, nursing journals, dental journals and core clinical journals in the last 10 years with studies addressing the general epidemiology of sports injuries in basketball.

Results In total, 268 articles were selected, of which 11 were eligible for the integrative review. A total of 12 960 injuries were observed, most of which occurred in the lower limbs (63.7%), with 2832 (21.9%) ankle injuries and 2305 (17.8%) knee injuries. Injuries in the upper limbs represented 12%–14% of the total injuries. Children and adolescents received head injuries more often compared with the other age and skill categories. In the adult category, there was an increased prevalence of injuries in the trunk and spine. In the upper limbs, hands, fingers and wrists were affected more frequently than the shoulders, arms and forearms. In the masters' category, there was an increase in the incidence of thigh injuries.

Conclusion The lower limbs were the most affected, with the ankle and knee joints having the highest prevalence of injuries regardless of gender and category. Further randomised studies, increased surveillance and epidemiological data collection are necessary to improve knowledge on sports injuries in basketball and to validate the effectiveness of preventive interventions.

INTRODUCTION

Created in the USA more than a century ago by James Naismith,¹ basketball has become one of the most popular sports in the world, particularly in the USA.^{2 3} In Brazil, basketball is one of the four most popular sports according to the Ministry of Sports.⁴

Despite all the benefits resulting from participation in sports—such as improved body composition, cardiorespiratory function, increased strength, improved self-esteem/

psychosocial well-being, weight control, and less abuse of alcohol and drugs, among others^{5–7}—participating in a sport with so much physical demand, such as basketball, where the athlete performs repetitive jumps during games and training, abrupt changes in direction, running and deceleration,⁸ may result in a greater risk of injury. This leads to an increase in health expenses and visits to doctors and hospitals, reduction in court time, and increased risk of new injuries.^{9 10}

Several studies have already been published describing injuries in basketball. Some focus on professional athletes,¹¹ others focus on college students¹² or high school students,^{13 14} and others on adult athletes.¹⁵ Some studies focus only on a specific region of the body or a specific diagnosis, such as concussion,¹⁶ shoulder¹⁷ or ankle injury,¹⁸ and many compare injury rates between sexes.¹⁹

The understanding of basketball injury epidemiology is an important first step in the development of targeted, evidence-based interventions to provide recommendations for injury prevention. The objective of this study was to perform an integrative review of the epidemiology of musculoskeletal injuries in basketball.

METHODOLOGY

Literature search

An electronic search was performed in the following databases: PubMed/MEDLINE, Embase, LILACS, and thematic databases included in the Portal de Pesquisa da Biblioteca Virtual em Saúde (Virtual Health Library Research Portal): BBO-Biblioteca Brasileira de Odontologia (Brazilian Library of Dentistry) and IBECs-Índice Bibliográfico Espanhol em Ciências da Saúde (Spanish Bibliographic Index in Health Sciences). Other sources of information were also included, such as nursing journals, dental journals, core clinical journals, and the Coordenação de Aperfeiçoamento de Pessoal de



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Nível Superior (CAPES; Brazilian Federal Agency for the Support and Evaluation of Graduate Education) Thesis Bank, which is a representative of the so-called *grey literature* and internet sites. Language or region filters were not included. The elaboration of the search strategies gave the research greater sensitivity by combining the terms extracted from the DeCS/MesH and synonyms: basketball, epidemiology, athletic injuries, sprains and strains. Thus, the eligibility criterion was to identify articles that discussed the general epidemiology of sports injuries in basketball.

To determine whether a study should be included, the titles and abstracts of all references obtained were evaluated by two medical reviewers. The extracted studies were assessed based on the inclusion and exclusion criteria. The inclusion criteria were as follows: (1) articles published in the last 10 years; (2) studies addressing the general epidemiology of sports injuries in basketball; and (3) athletes of any age, of both sexes, and professional, amateur and recreational basketball practitioners. The exclusion criteria were as follows: (1) review articles; (2) case reports; (3) articles dealing with Paralympic sports; (4) studies on the general epidemiology of sports injuries, including basketball, that did not present specific injury percentages for each sport; (5) items that solely addressed some type of specific basketball injury, for example, articles reporting knee injuries in basketball, or

basketball dental injuries and basketball concussions; (6) articles that presented in the results section the percentages of the injuries without specifying the region of the body (eg, foot, ankle, knee and so on), referring to only general terms as upper limbs, lower limbs and trunk; and (7) articles that only addressed more prevalent injuries in emergency departments or surgical basketball injuries because these data reveal a portion of possible basketball injuries rather than overall totality/epidemiology. The possible inconsistencies were identified, discussed and resolved by consensus.

Procedures for creating the database

To create this database, the following steps were taken: (1) extraction of the number of injuries detailed by the site of each study—when the study did not present the total number of injuries but did report the relative frequency, the absolute frequencies were computed by multiplying the total number of injuries by the relative frequencies; (2) checking and rechecking of total injuries in each study; and (3) organisation of the total absolute frequencies, by sex and by category of the participant.

Eleven studies were included in this review, as shown in [figure 1](#). The main characteristics of the studies included in the integrative review are described in [table 1](#).

The objectives of the 11 studies included in the analysis ([table 1](#)) were as follows: to verify the association

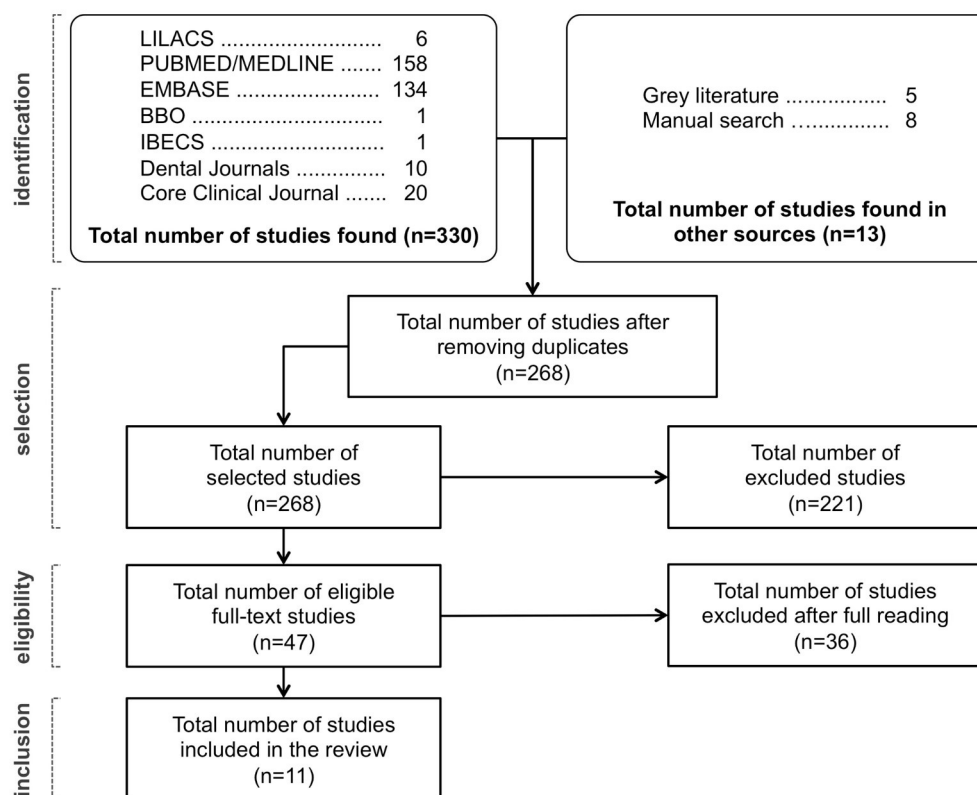


Figure 1 Selection of the studies surveyed in the electronic databases and grey literature. Preferred Reporting Items for Systematic Reviews and Meta-Analyses algorithm. BBO, Biblioteca Brasileira de Odontologia (Brazilian Library of Dentistry); IBECS, Índice Bibliográfico Espanhol em Ciências da Saúde (Spanish Bibliographic Index in Health Sciences).

Table 1 Main characteristics of the studies included in the integrative review on basketball epidemiology

Journal	Year	Title	Authors	Method	Objective	Local	Category	Period	Sample size
<i>The American Journal of Sports Medicine</i>	2008	The epidemiology of US high school basketball injuries, 2005–2007	Laurel A Borowski, Ellen E Yard, Sarah H Fields, R Dawn Comstock	Retrospective. Descriptive epidemiology study.	Adolescents by gender (check rates and patterns of basketball injuries between genders and by type of exposure).	EUA	Adolescents	2005–2007	1.94*
<i>Journal of Athletic Training</i>	2014	Epidemiologic comparison of injured high school basketball athletes reporting to emergency departments and the athletic training setting	Erica N Fletcher, Lara B McKenzie, R Dawn Comstock	Retrospective. Descriptive epidemiology study.	Incidence in adolescents (comparison of injury patterns in emergency departments and in the athletic training setting).	EUA	Adolescents	2005–2011	1.68*
<i>Journal of Athletic Training</i>	2007	Subsequent injury patterns in girls' high school sports	Mitchell J Rauh, Caroline A Macer, Ming Ji, Denise L Wiksten	Prospective. Observational cohort.	Comparison of subsequent injuries between sports with girls.	EUA	Adolescents	1995–1997	6083
<i>Acta Ortopédica Brasileira</i>	2007	Incidência de lesões musculoesqueléticas em atletas de elite do basquetebol feminino	Alexandre S da Silva, Rene J Abdalla, Mauro Fisberg	Prospective. Prospective analysis.	Incidence in women.	Brazil	Professional	1999–2000	66
<i>The Physician and Sportsmedicine</i>	2014	Epidemiology of basketball, soccer, and volleyball injuries in middle-school female athletes	Kim D Barber Foss, Greg D Myer, Timothy E Hewett	Prospective. Observational studies—transversal or cross-section.	Injury in children (incidence of injury in female athletes).	EUA United States	Children	2009–2010	162
<i>Journal of Sports Sciences</i>	2016	Quality of life perception of basketball master athletes: association with physical activity level and sports injuries	NB Moreira, O Mazzardo, GC Vagetti, V De Oliveira, W De Campos	Prospective. Non-probabilistic cross-sectional character with correlational descriptive design.	Masters injuries, (association between SI, PA) and injuries with related dimensions perception of HRQoL in basketball master athletes.	Brazil	Masters	2012	410
<i>Journal of Science and Medicine in Sport</i>	2017	Game injuries in relation to game schedules in the National Basketball Association	Masaru Teramoto, Chad L Cross, Daniel M, Cushman, Travis G Maak, David J Petron, Stuart E Willick	Prospective. Prospective cohort study.	Check association between game schedule and injuries.	EUA -United States	Professional	2012–2015	1443
<i>Science & Sports</i>	2015	Injuries of high-level female basketball players during one competitive season	M Buffet, N Morel, M Navacchia, J Voyezd, J Vella-Boucaude, P Edouard	Prospective. Study prospective cohort.	Incidence in women (professionals in the France, to define prevention strategies).	France	Professional	2012–2013	11
<i>Sports Medicine, Arthroscopy, Rehabilitation, Therapy and Technology</i>	2012	Incidence and pattern of injuries among adolescent basketball players in Nigeria	Oluwatoyosi Babatunde Alex Owoeye, Ashiyat Kehinde Akodu, Bayonle Matt Oladokun, Sunday Rufus Akinwumi Akinbo	Prospective. Prospective cohort study.	Incidence in adolescents (in Nigeria).	Nigeria	Adolescents	2010	141
<i>Science & Medicine</i>	2011	Injury reporting rates and injury concealment patterns differ between high-school cirque performers and basketball players	Ashley S Long, Jatin P Ambeaonkar, Patty M Fahringer	Prospective. Observational cohort.	Compare with other sport/activity.	EUA - United States	Adolescents	2010–2011	20
<i>The American Journal of Sports Medicine</i>	2006	Injury risk in professional basketball players: a comparison of Women's National Basketball Association and National Basketball Association athletes	John R Deitch, Chad Starkey, Sheri L Walters, J Bruce Moseley	Retrospective. Observational cohort.	Compare sex.	EUA - United States	Professional	1996–2002	1145

*The study did not present the total number, but rather the relative frequency; the absolute frequencies were computed by multiplying the total number of injuries by the relative frequencies. HRQoL, health-related quality of life; PA, physical activity; SI, sports injuries.

between game schedule and injuries; to compare basketball with other sports/physical activities or sports; to compare subsequent injuries among sports; to verify differences in injuries between sexes; to compare injury patterns in emergency departments and in the athletic training setting; to assess the incidence of injuries; and to assess the association between physical activity level, physical activity dependence and injuries with the dimensions related to the perception of health-related quality of life and health. Despite the different objectives of the included studies, in all studies it was possible to verify the number of basketball injuries in each part of the body, either through the absolute number that was indicated in the study or through the absolute frequencies multiplied by the total number of injuries. In this way, the following results were obtained.

Inferential procedures

In the inferential analysis, the following software were used: R (V.3.3.2) and RStudio (V.1.0.136). The 'meta' library was adopted for the estimation of meta-analysis models. The overall proportions of knee and ankle and foot injuries were estimated, along with the respective CIs and weights for each study. Tests were also performed to verify whether the OR between injuries at different sites was the same (OR=1). For this analysis, the knee was adopted as a reference site.

RESULTS

Characteristics of the identified studies

Descriptive statistics of the studies

A total of 268 articles were selected, of which 11 articles were eligible for the integrative review. Of the studies included in the study, it was possible to extract the number of absolute injuries in females in seven studies.^{20–26} For males, five studies were used to extract the number of injuries.^{20 24 26–28} Two other studies did not specify the gender, and the data were only used for the total sum of the injuries.^{29 30}

With regard to the region of the participants, seven (63.6%) studies were from the USA, two (18.2%) were from Brazil, one (9.1%) was from France and one (9.1%) was from Nigeria. With regard to the age and level of skill category, most of the studies addressed injuries in adolescents (45.5%, 5 studies), followed by injuries in professionals (36.4%, 4 studies, [table 1](#)). Children and masters were cited in only one study each, which represented 9.1% and 9.1% of the studies, respectively.

Descriptive statistics of injuries

In total, 12 960 injuries were computed and extracted from the studies ([table 2](#)). The knee and the ankle were the most affected sites, with 2832 (21.9%) and 2305 (17.8%) injuries, respectively. When analysed separately, this trend was repeated for injuries in both females and males. With regard to injuries in females, 19.5% of injuries occurred in the ankle and 20.6% occurred in the knee. The third most affected region in females was the thigh,

hip and leg, which accounted for 17.5% of injuries. In males, 28.4% of injuries occurred in the ankle and foot, followed by the thigh, hip and leg (19.3%) and the knee (17.5%). When the injuries were analysed according to the age/level of skill category, the site with the most injuries in children and adolescents was the ankle and the foot (37.7%, 2807 injuries), followed by the knee (16.3%, 1214 injuries), head and neck (13.7%, 1024 injuries), and the hands, fingers and wrists (8.9%, 662 injuries). For professional athletes, the injury frequencies were as follows: 24.8% (1310 injuries) of injuries occurred in the foot and the ankle, followed by the thigh, hip and leg with 1074 injuries (20.4%), the knee with 19.5% (1027 injuries), and the trunk and spine with 586 injuries (11.1%). Only one study referred to the masters' category, and in this study 31.4% of the injuries (75 injuries) occurred in the thigh, hip and leg, followed by the knees with 64 injuries (26.8%) and the ankle and the foot with 39 injuries (16.3%) ([table 2](#)).

Inferential analysis

The proportions of injuries were estimated by meta-analysis models, which weighted injury frequencies by study sizes. [Figure 2](#) presents the proportions of knee and ankle and foot injuries estimated by fixed-effects and random-effects models and the CIs and weight of each study in this estimation. Notably, there is significant heterogeneity in the studies, measured by the I^2 statistic (95% and 97%, respectively). The estimated proportion of knee injuries was 0.18 (95% CI 0.17 to 0.19) for the fixed-effects model and 0.22 (95% CI 0.18 to 0.27) for the random-effects model. The estimated proportion of ankle and foot injuries was 0.33 (95% CI 0.32 to 0.33) for the fixed-effects model and 0.29 (95% CI 0.24 to 0.34) for the random-effects model.

ORs between injury sites

The ORs between injuries were also estimated using a meta-analysis model, using knee injuries as the reference, which was the most frequent site of injury. With ankle and foot combined, this category of injuries proportionally exceeded that of knee injuries. However, this category is less specific.

The results of the OR comparison tests in the fixed-effect models are presented in [table 3](#). The test evaluates whether the OR is equal to 1 and rejects the hypothesis in cases of low p values ($p < 0.05$). All OR values were greater than 1, except for the ankle and foot, which had a value less than 1. The p value for all comparisons was statistically significant ($p < 0.0001$). Thus, the probability of knee injury was greater than the probability of injury to the thigh, hip and leg, head and neck, trunk and spine, shoulder arm and forearm, and hands, fingers and wrists. The probability of knee injury was only lower than the probability of ankle or foot injury. It was not possible to calculate the comparisons of knee with ankle only and knee with foot only using the set of studies.

Table 2 Injury percentages by anatomical segments in relation to total number, female sex, male sex, children and adolescents, professionals, and masters

	Total**		Female**‡		Male**†		Children and adolescents§		Professionals¶		Masters†**	
	Injuries (n)	%	Injuries (n)	%	Injuries (n)	%	Injuries (n)	%	Injuries (n)	%	Injuries (n)	%
Total	12 960	100.0	4291	100.0	4602	100.0	7449	100.0	5272	100.0	239	100.0
Ankle and foot	4156	32.1	1302	30.3	1308	28.4	2807	37.7	1310	24.8	39	16.3
Ankle	2832	21.9	837	19.5	670	14.6	1910	25.6	922	17.5	–	–
Foot	683	5.3	197	4.6	265	5.8	295	4.0	388	7.4	–	–
Not determined	641	4.9	268	6.2	373	8.1	602	8.1	–	–	39	16.3
Knee	2305	17.8	882	20.6	807	17.5	1214	16.3	1027	19.5	64	26.8
Thigh, hip and leg	1784	13.8	752	17.5	886	19.3	635	8.5	1074	20.4	75	31.4
Head and neck	1468	11.3	417	9.7	384	8.3	1024	13.7	437	8.3	7	2.9
Hands, fingers and fist	1133	8.7	369	8.6	386	8.4	662	8.9	454	8.6	17	7.1
Trunk and spine	975	7.5	325	7.6	508	11.0	371	5.0	586	11.1	18	7.5
Shoulder, arm and forearm	585	4.5	182	4.2	267	5.8	238	3.2	328	6.2	19	7.9
Others	554	4.3	62	1.4	56	1.2	498	6.7	56	1.1	–	–

*Includes all studies, whether for females, males or both.

†For comparison and simplification purposes, seven lesions classified as head and chest in the original study were included in the head and neck category.

‡Includes all studies presenting discrimination of lesions for females.

§Includes all studies, whether for females, males or both for children and adolescents.

¶Includes all studies, whether for females, males or both for professional athletes.

**Only one study addresses a masters' category.

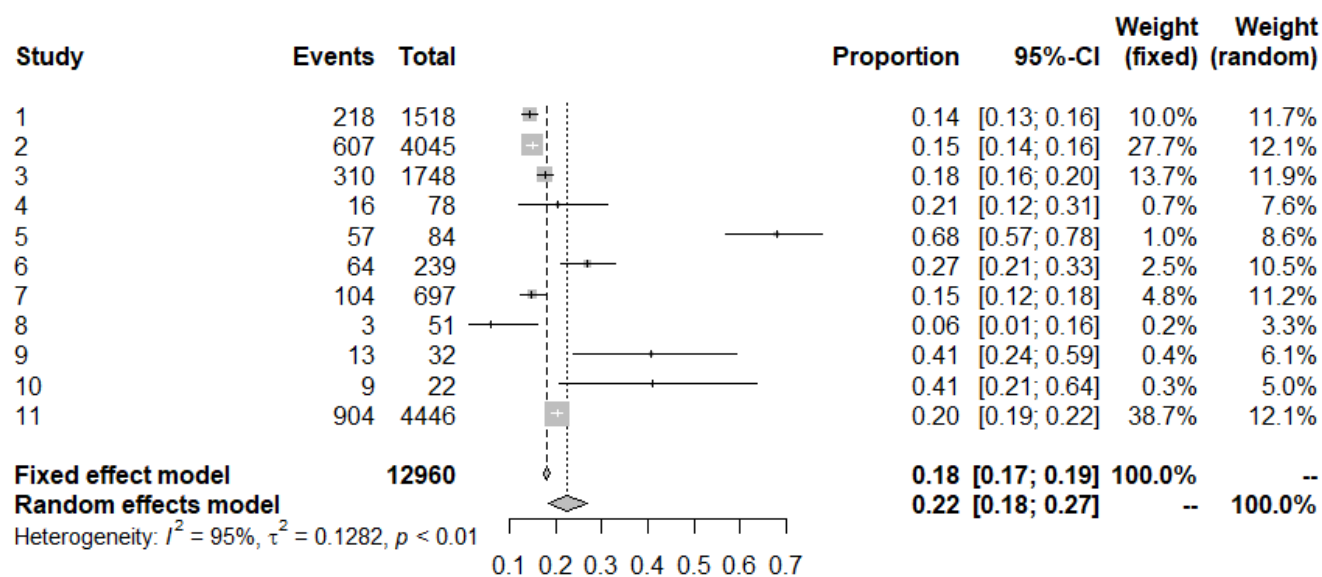


Figure 2 Proportions of knee and ankle and foot injuries estimated by fixed-effects and random-effects models and the CIs and weight of each study in this estimation knee.

DISCUSSION

In this study, more than 12 000 basketball injuries were analysed from the 11 included studies, and the results showed that there were more injuries in the lower limbs (63.7% of the injuries), regardless of gender (male, 65.2%; female, 68.4%) or level (professionals 64.7%, master 74.5%, and children and adolescents 62.5%). These data are in accordance with the literature.^{31–33}

In a Women's National Basketball Association and NBA six-season retrospective study, Deitch *et al*²⁴ concluded that the lower limbs (65%) were the most common site of injury in basketball. Of the 5272 injuries of the professional category included in this study, 3411 occurred in the lower limbs, representing 64.7% of the total injuries reported.

According to the specific anatomical region, the largest proportion of injuries occurred in the ankle (2832 injuries, 21.9%), followed by the knee (2305 injuries, 17.8%). Most authors point to the ankle as the most common site of injury^{13 14 31–34}, however, some authors report that the knee is the most affected region.^{35 36}

When analysed separately, 19.5% of injuries occurred in the ankle and 20.6% in the knee in females, whereas

these values were 14.6% and 17.5% in males, respectively. In the children and adolescent category, ankle injuries accounted for 25.6% and knee injuries accounted for 16.3%. In professionals, ankle and knee injuries accounted for 17.5% and 19.5% of all injuries, respectively. Finally, in master athletes, knee injuries accounted for 26.8%, and foot and ankle injuries accounted for 16.3%. It was not possible to differentiate between foot and ankle injuries for the masters' category. In that category, only one study and a small number of injuries were found compared with the other categories. The percentages in knee and ankle injuries varied between the sexes and the levels of sport, making it difficult to affirm which is the most prevalent, as previously described.

Both knee and ankle injuries are the most prevalent. As shown by the inferential analysis and the OR values (table 3), which uses knee injuries as a reference and compares it with the other anatomical regions categorised in this study, the probability of knee injury occurring is higher than that of all regions except for the ankle and foot, which is statistically significant because in all comparisons $p < 0.001$.

Table 3 Estimated values of OR compared with knee injuries, limits of the 95% CI and p value for the hypothesis of OR=1

Local	OR	Lower limit (95% CI)	Upper limit (95% CI)	P value
Ankle and foot	0.4625	0.4365	0.4900	<0.0001
Thigh, hip and leg	1.3590	1.2701	1.4541	<0.0001
Head and neck	1.6838	1.5697	1.8062	<0.0001
Trunk and spine	2.6710	2.4669	2.8920	<0.0001
Shoulder, arm and forearm	4.6028	4.1880	5.0586	<0.0001
Hands, fingers and fist	2.2531	2.0891	2.4300	<0.0001
Other (except previous ones)	4.7209	4.2898	5.1954	<0.0001

Because basketball is a sport that involves sudden changes in direction, side shifts, jumps, and more importantly landings, these results are not surprising. It would be logical and expected that injuries in the lower limbs would be the most prevalent.⁸

With regard to upper limb injuries, injuries to the hands, fingers and wrists (1133, 8.7%) predominated over shoulder, arm and forearm injuries (585, 4.5%).³⁷ This was observed in all categories analysed: for females, hands, fingers and wrists represented 8.6% (369) of injuries, and shoulders, arms and forearms represented 4.2% (182) of injuries; for males, hands, fingers and wrists represented 8.4% (386) of injuries, and shoulders, arms and forearms represented 5.8% (267) of injuries. For the age/level of skill categories, the data were similar except for the masters' category, which presented essentially the same number of injuries in the hands, fingers and wrists, and in the shoulder, arm and forearm. However, for this category, only one study and a small number of injuries were reported. For children and adolescents, injuries in the hands, fingers and wrists represented 8.9% (662) of injuries, and injuries in the shoulders, arms and forearms represented 3.2% (238) of injuries. For professionals, injuries in the hands, fingers and wrists represented 8.6% (454) of injuries, and injuries in the shoulder, arm and forearm represented 6.2% (328) of injuries. For masters, injuries in the hands, fingers and wrists represented 7.1% (17) of injuries, and injuries in the shoulders, arms and forearms represented 7.9% (19) of injuries. These data are also consistent with the literature, with some studies reporting 12%–14% of injuries occurring in the upper limbs.^{33,38}

The percentage of injuries in the upper limbs increases when the sample is obtained from emergency departments, as reported by the studies.^{39,40} When hand, finger and wrist injuries were analysed separately among children and adolescents and professionals, 662 injuries occurred in children and adolescents and 454 occurred in professionals. These numbers represent 50.81% and 49.19% of all injuries in children and adolescents and professionals, respectively. Therefore, for these categories, the probability of injury to the hands, fingers and wrists is the same.

Considering the importance of the increase in the diagnosis of concussions, a brief analysis of the injuries in this anatomical region is valid, although combined with neck injuries. In total, there were 1468 injuries in this region, representing 11.3% of total injuries. In females, 417 injuries (9.7%) occurred in this region, and in males 384 injuries (8.3%) occurred in this region. Because in some studies it was not possible to differentiate injuries by sex, the sum of injuries between males and females was not equal to the total injuries reported. The value reported by the studies for the injuries in these anatomical regions varied between 8.9% and 14%.^{24,31–33}

Excluding the masters' class, which had a much smaller number of reported injuries, head and neck injuries were compared between the professional and children and

adolescents categories, with 437 and 1024 injuries, respectively. Proportionally, in relation to the total number of injuries reported by each category, these numbers represent 62% and 38% of injuries in children and adolescents and adults, respectively. Therefore, there is a tendency for children and adolescents to suffer more head and neck injuries than those in the professional category. There is also a study showing that this is a trend in teenage male basketball players because of the increase in the level of physical contact now observed among players of this category.³¹

A total of 975 injuries occurred in the trunk and spine, representing 7.5% of all injuries. Of these 975 injuries, only 371 occurred in children and adolescents, and 586 occurred in professionals. Of the total trunk and spine injuries reported, 31% and 69% occurred in children and adolescents and professionals, respectively. A higher prevalence of trunk and spine injuries was observed in professionals.

Only 5% of all injuries reported for children and adolescents occurred in the trunk and spine. For professionals, this number was 11.1%. According to Starkey³³ in a study on NBA players, only 6.9% of all injuries occurred in this region; however, only injuries to the lumbar and thoracic spine were counted, and other injuries that occurred in the trunk were not considered. This fact could explain the observed difference between the values reproduced by this study and the study by Starkey.³³

Other authors have obtained results for adolescents in which trunk and spine injuries account for 11.4% to 13.5% of all injuries.^{31,32} In this study, there was not a category for adolescents only, which could explain the difference in results: adolescents may have a greater proportion of injuries in the trunk and spine compared with the group of children and adolescents together. Because adolescence is an intermediary phase between the child and the adult phases, it seems logical that adolescents have a higher spinal injury rate than children. The trunk and spine was the fourth most prevalent injury region in professionals. For the masters' category, only 18 trunk and spine injuries were reported; this number is very small compared with the other categories. Again, this occurred because there was only one study reporting injuries in the masters' category.

LIMITATIONS OF THE STUDY

Among the existing limitations is the fact that after applying the search strategy, only one study was found in the masters' category and it included only male athletes, accounting for a total of 239 injuries. In addition, only one study in the children category was also found, with only 84 injuries in 162 female athletes. For the descriptive statistics of the injuries, the study with children was included along with the adolescents' category, resulting in 7449 injuries among children and adolescents.

Another limitation was the set-up of the database: because each study used a standard to divide the injuries between the various parts of the body, some regions

were common, such as the knee. However, the injuries were often grouped into categories such as the foot and ankle and trunk and spine. These regions were divided according to the previous tables, minimising possible errors, but at times it was impossible to differentiate injuries grouped into specific categories, such as separating foot and ankle injuries in some studies. Other times, injuries classified as head and thorax in the original study were included in the head and neck category.

The most adequate technique for the calculation of this epidemiology would be the injury index given the athlete's exposure (in game, training or total) per thousand hours. Limitations prevented calculating the index of injuries due to the athlete's exposure, given the different calculation methods. To obtain this index, each athlete's hours spent training or playing and the number of injuries must be considered. Not all studies have reported this injury index given the athlete's exposure. Additionally, there was great heterogeneity in the studies, measured by the I^2 statistic (95% and 97%, respectively).

CONCLUSION

Knowledge of the general epidemiology of basketball injuries is a first step for effective preventive measures to be implemented to reduce the incidence of injuries and their losses, including expenses associated with doctors, hospitals and athletes' leave of absence. The lower limbs are the most affected injury region in basketball players, regardless of sex and category. Within anatomical regions, knee and ankle injuries are the most prevalent. The probability of injury to the hands, fingers and wrist is the same for children, teenagers and professional adults. In the category of children and adolescents, there was a higher prevalence of head and neck injuries compared with the other categories. For professionals, there was a higher prevalence of trunk and spine injuries.

Contributors Federal University of São Paulo.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent for publication Not required.

Provenance and peer review Not commissioned; internally peer reviewed.

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REFERENCES

- Cantwell JD. The physician who invented basketball. *Am J Cardiol* 2004;93:1075–7.
- United States Department of Labor, 2008. Sports and exercise. Available from: <https://www.bls.gov/spotlight/2008/sports/> [Accessed 9 Feb 2018].
- National Federation of State High School Associations, 2017. High school athletics participation survey, 2015–16. Available from: http://www.nfhs.org/ParticipationStatistics/PDF/2015-16_Sports_Participation_Survey.pdf [Accessed 1 Jun 2017].
- Brasil (Ministério do Esporte), 2018. A prática de esporte no Brasil. Diagnóstico Nacional do Esporte. Available from: <http://www.esporte.gov.br/diesporte/index.html> [Accessed 9 Feb 2018].
- United States Department of Health and Human Services, 1996. Surgeon general's report on physical activity and health. 1999. Available from: <http://www.cdc.gov/nccdphp/sgr/sgr.htm> [Accessed 18 Dec 2007].
- World Health Organization, 2017. Physical activity and young people. Available from: http://www.who.int/dietphysicalactivity/factsheet_young_people/en/ [Accessed 1 Jun 2017].
- Harrison PA, Narayan G. Differences in behavior, psychological factors, and environmental factors associated with participation in school sports and other activities in adolescence. *J Sch Health* 2003;73:113–20.
- Backx FJ, Beijer HJ, Bol E, et al. Injuries in high-risk persons and high-risk sports. A longitudinal study of 1818 school children. *Am J Sports Med* 1991;19:124–30.
- Conn JM, Annett JL, Gilchrist J. Sports and recreation related injury episodes in the US population, 1997–99. *Inj Prev* 2003;9:117–23.
- de Loës M, Dahlstedt LJ, Thomée R. A 7-year study on risks and costs of knee injuries in male and female youth participants in 12 sports. *Scand J Med Sci Sports* 2000;10:90–7.
- Drakos MC, Domb B, Starkey C, et al. Injury in the national basketball association: a 17-year overview. *Sports Health* 2010;2:284–90.
- Meeuwisse WH, Sellmer R, Hagel BE. Rates and risks of injury during intercollegiate basketball. *Am J Sports Med* 2003;31:379–85.
- Messina DF, Farney WC, DeLee JC. The incidence of injury in Texas high school basketball. A prospective study among male and female athletes. *Am J Sports Med* 1999;27:294–9.
- Powell JW, Barber-Foss KD. Injury patterns in selected high school sports: a review of the 1995–1997 seasons. *J Athl Train* 1999;34:277–84.
- Cumps E, Verhagen E, Meeusen R. Prospective epidemiological study of basketball injuries during one competitive season: ankle sprains and overuse knee injuries. *J Sports Sci Med* 2007;6:204–11.
- Kelly JP. Concussion in sports and recreation. *Semin Neurol* 2000;20:165–72.
- Kocher MS, Waters PM, Micheli LJ. Upper extremity injuries in the paediatric athlete. *Sports Med* 2000;30:117–35.
- McKay GD, Goldie PA, Payne WR, et al. Ankle injuries in basketball: injury rate and risk factors. *Br J Sports Med* 2001;35:103–8.
- Powell JW, Barber-Foss KD. Sex-related injury patterns among selected high school sports. *Am J Sports Med* 2000;28:385–91.
- Borowski LA, Yard EE, Fields SK, et al. The epidemiology of US high school basketball injuries, 2005–2007. *Am J Sports Med* 2008;36:2328–35.
- Rauh MJ, Macera CA, Ji M, et al. Subsequent injury patterns in girls' high school sports. *J Athl Train* 2007;42:486–94.
- Silva ASda, Abdalla RJ, Fisberg M. Incidência de lesões musculoesqueléticas em atletas de elite do basquetebol feminino. *Acta Ortopédica Brasileira* 2007;15:43–6.
- Barber Foss KD, Myer GD, Hewett TE. Epidemiology of basketball, soccer, and volleyball injuries in middle-school female athletes. *Phys Sportsmed* 2014;42:146–53.
- Deitch JR, Starkey C, Walters SL, et al. Injury risk in professional basketball players: a comparison of Women's National Basketball Association and National Basketball Association athletes. *Am J Sports Med* 2006;34:1077–83.
- Buffet M, Morel N, Navacchia M, et al. Blessures chez des joueuses de basket-ball féminin de haut niveau durant une saison. *Sci Sports* 2015;30:134–46.
- Owoeye OBA, Akodu AK, Oladokun BM, et al. Incidence and pattern of injuries among adolescent basketball players in Nigeria. *Sports Medicine, Arthroscopy, Rehabilitation, Therapy & Technology* 2012;4:4–15.
- Moreira NB, Mazzardo O, Vagetti GC, et al. Quality of life perception of basketball master athletes: association with physical activity level and sports injuries. *J Sports Sci* 2016;34:988–96.
- Teramoto M, Cross CL, Cushman DM, et al. Game injuries in relation to game schedules in the National Basketball Association. *J Sci Med Sport* 2017;20:230–5.
- Fletcher EN, McKenzie LB, Comstock RD. Epidemiologic comparison of injured high school basketball athletes reporting to emergency departments and the athletic training setting. *J Athl Train* 2014;49:381–8.
- Long AS, Ambegaonkar JP, Fahringer PM. Injury reporting rates and injury concealment patterns differ between high-school cirque performers and basketball players. *Med Probl Perform Art* 2011;26:200–5.

31. Dick R, Hertel J, Agel J, *et al.* Descriptive epidemiology of collegiate men's basketball injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2003-2004. *J Athl Train* 2007;42:194-201.
32. Agel J, Olson DE, Dick R, *et al.* Descriptive epidemiology of collegiate women's basketball injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2003-2004. *J Athl Train* 2007;42:202-10.
33. Starkey C. Injuries and illnesses in the national basketball association: a 10-year perspective. *J Athl Train* 2000;35:161-7.
34. Zelisko JA, Noble HB, Porter M. A comparison of men's and women's professional basketball injuries. *Am J Sports Med* 1982;10:297-9.
35. DeHaven KE, Lintner DM. Athletic injuries: comparison by age, sport, and gender. *Am J Sports Med* 1986;14:218-24.
36. Carazzato JG, Campos LAN, Carazzato SG. Incidência de lesões traumáticas em atletas competitivos de dez tipos de modalidades esportivas. *Rev Bras Ortop* 1992;27:745-58.
37. Sonzogni JJ, Gross ML. Assessment and treatment of basketball injuries. *Clin Sports Med* 1993;12:221-37.
38. Newman JS, Newberg AH. Basketball injuries. *Radiol Clin North Am* 2010;48:1095-111.
39. Randazzo C, Nelson NG, McKenzie LB. Basketball-related injuries in school-aged children and adolescents in 1997-2007. *PEDIATRICS* 2010;126:727-33.
40. Sytema R, Dekker R, Dijkstra PU, *et al.* Upper extremity sports injury: risk factors in comparison to lower extremity injury in more than 25 000 cases. *Clin J Sport Med* 2010;20:256-63.