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Original research

Profile and cost of sport and exercise-related hand and wrist injuries with Emergency Department presentation

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ABSTRACT

Objectives: Injuries to the hand and wrist from sport and exercise are common and costly. This cost-of-illness analysis was performed to estimate the economic implications of hand and wrist injuries that were sustained as a result of participation during sport or exercise.
Perspective: Cost estimates were calculated from resource use in the emergency, inpatient and outpatient settings from the perspective of one public healthcare service.
Setting: Alfred Health, a large public health service with two emergency departments located in Victoria, Australia.
Methods: This descriptive epidemiological study used ICD-10 diagnostic codes and electronic billing records to identify 778 potential cases for inclusion. Electronic medical records were screened and reviewed to extract demographic and patient care journey data.
Results: 692 individuals, (n = 761 individual zone of injuries), were included. Australian Rules Football (ARF) was the largest contributor to injuries (20.2%) followed by riding bicycles (15.9%. The total cost of all injuries was $790,325, with a median cost per case of $278 [IQR $210–$282] in the Emergency Department n = 692, $3328 [IQR $2242–$6441] in the inpatient setting n = 76 and $630 [IQR $460–$870] in the outpatient setting n = 244.
Conclusions: Hand and wrist injuries sustained from sport and exercise contribute to a significant financial burden on the healthcare system. Future research that considers the costs that occur outside of the public healthcare service is required estimate the burden associated with these injuries comprehensively. Injury prevention programs may mitigate the observed injury trends.

Practical implications

- Costs presented are drawn from records of a single health service. As they do not include ambulance, general practitioner, or other community and private facility health costs, they are likely to substantially underestimate total burden. Societal costs are likely to be very much higher, as people with significant hand or wrist injury will experience impacts on their usual employment as well as ability to drive or care for their families.
- Injury prevention programs should be considered as potential avenues to decrease the economic burden associated with avoidable hand and wrist injuries sustained from participation in sport and exercise.
- Targeted strategies to reduce the number of failed to attend appointments should be considered within practice settings to decrease avoidable expenditure.

1. Introduction

Sport is one of the defining cultural pastimes and interests in Australia. The broader benefits of sport are increasingly acknowledged by governments, businesses and communities[1,2] with estimates of participation rates within the Australian population varying from 28 to 40% for organised physical activity and 60–70% for non-organised physical activity.[3] Sport is an effective means for combating the rising rates of obesity and chronic illness, crime rates, as well as improving levels of physical and mental health.[4,5] Despite these health and social benefits, organised and non-organised sport or exercise also has the potential to cause serious injury at a significant cost to both the individual, their family and broader society.[6]

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In Australia, it is estimated that annually one in seventeen sport-playing individuals sustain an injury that is significant enough to miss a game or training, leave the field of play, or seek medical or first aid treatment.[7] In 2011-12 approximately 36,000 people aged 15 years and older were hospitalised as the result of an injury while playing sport and spent a total of 79,000 days in hospital.[6] In addition to the impact on the individual (i.e. pain, discomfort, physical impairment, loss of productivity), sports injuries place a heavy burden on Australian society with costs upwards of $2 billion dollars each year.[8]

While injuries to the shoulder and knee receive much attention, approximately 25% of sports injuries involve the hand or wrist.[9] Furthermore, 20% of sports-related fractures are sustained in the hand or wrist, second only to the knee/lower leg (23%).[6] In Australia, no published evidence currently exists that examines the epidemiology, costs, and medical care resource consumption for sports-related acute hand and wrist injuries due to the absence of a national systematic patient data repository. Accurate information regarding costs and resources used in the provision of healthcare is essential to policymakers, funders and health service managers for planning and resource distribution.[10]

This cost-of-illness analysis was performed with the purpose of estimating the economic implications of hand and wrist injuries that were sustained as a result of participation during sport or exercise from the perspective of one Australian public hospital health service. Specifically, we aimed to:

1 estimate the costs associated with resource use following a sport or exercise-related hand or wrist injury from the perspective of the healthcare service: and
2 illustrate the demographic profile, patient care journey, and resources used by this patient population.

2. Methods

The target population for this cost-of-illness analysis was patients of any age who required an Emergency Department (ED) presentation within the study setting for an acute hand or wrist injury sustained while engaged in sport or exercise.

Using ICD-10 diagnostic codes involving the hand or wrist (refer Table A1 5028 patients from electronic billing records presenting to either the Alfred or Sandringham hospital EDs from July 1st, 2014 to June 30th, 2015 were identified.[11] The listed mechanism of injury contained within the electronic billing records were screened to identify patients who had presented with injuries that were as a result of participation in a sport (which may have been in a formal, informal or training setting) or an exercise activity (defined as a "planned, structured, and repetitive bodily movement done to improve or maintain one or more components of physical fitness" (p.129)).[12] For example, cases that were reported to occur from walking were excluded as it was not considered exercise using this definition; however, cases that occurred from jogging or running were included. This secondary analysis resulted in 778 potential cases for inclusion in this study. The full electronic medical record of each case identified in the screening process was reviewed to ensure the following selection criteria were met (1) the injury was the result of participation in a sport or exercise, (2) the injury was sustained to the hand and/or wrist, (3) the hand and/or wrist injury was the primary reason for presentation to the ED, and (4) sufficient detail was contained in the medical record to allow for extraction and analysis purposes. Using data extracted from the electronic medical records, we assigned a primary injury type as either (1) fracture, (2) joint injury, (3) laceration, (4) combination injury, (5) soft tissue injury, or (6) tendon injury.

The study setting was Alfred Health, one of Australia's major public health services, which has three public hospital campuses (two with emergency departments), as well as several outpatient clinics and a range of community services. The Alfred Hospital is a 680-bed major tertiary referral teaching hospital that is a major provider of specialist state-wide services to residents of Victoria that has about 65,000 ED visits per year. The Sandringham Hospital is a 100-bed medium tertiary referral teaching hospital and has about 34,000 ED visits per year. The health service is responsible for serving approximately 700,000 residents within the state of Victoria, owing to its specialised health services. Ethics was approved by Alfred Health (233/16) and Monash University (CF16/2268 – 20160001119).

We used an incidence-based approach for our cost-analysis, where we estimated the lifetime costs of a condition from its onset to its disappearance (in this instance, the completion of treatment in the study setting), to estimate the cost burden over a determined period of time.[13] Medical costs were estimated from the perspective of Alfred Health and were calculated for all resources used during ED presentations, inpatient surgical procedures, and outpatient appointments (refer Table A2 for included cost components). As traditional with this method, morbidity and mortality were not considered.[13]

Indirect costs due to loss of productivity (e.g. paid or unpaid work), child-care, transport or other out-of-pocket costs are not included in our cost estimates. As the study setting was restricted to one public health network, costs associated with resources used prior to presentation (e.g. ambulance, other hospital ED presentation, general practitioner (GP) consultation) or after treatment within the study setting (e.g. private inpatient admission, additional private surgical management, or private medical or allied health outpatient management) were also not included.

Details relating to costs incurred from resource use in the ED and inpatient settings were extracted from hospital billing records that are collected for the health service's clinical, admissions and financial records systems. These cost estimates were not adjusted (0% discount rate) and are presented as billed/recorded during the data collection period. All outpatient resource use (e.g. medical, nursing and therapy appointments) was extracted from electronic medical records, with costs calculated using unit cost prices (2015) (refer Table A2). The total cost of each individual case was estimated by summing all publicly funded resources used during the episode of care within the study setting.

Demographic data (e.g. age, occupation, hand dominance), injury details (e.g. sport or exercise that resulted in injury, location of injury, hand injured), inpatient length of stay (LOS), patient care journey (e.g. general practitioner (GP) appointments prior to ED presentation, outpatient discharge destination) and outpatient resource use (e.g. number or medical, hand therapy (HT), physiotherapy (PT) or failure to attend (FTA) appointments) were extracted from electronic medical records. Where the individual's primary work occupation was reported, it was classified using the Australian Standard Classification of Occupations (ASCO).[14]

Where appropriate, similar sport or exercise types were grouped together for analysis. For example, injuries sustained while using skateboards, scooters or rollerblades were combined into one category. Similarly, injury types were grouped together for analysis. For example, volar-plate or collateral ligament injuries of the finger with/without avulsion fractures were classified as joint injuries, while both tendinous and bony mallet injuries were classified as a tendon injury.

Normality of data was assessed before analysis. Descriptive statistics were used to report epidemiological, demographic and cost data. A biostatistician checked the data analysis procedures to ensure the accuracy of reported findings. All reported costs are presented in 2015 Australian Dollars (AUD).

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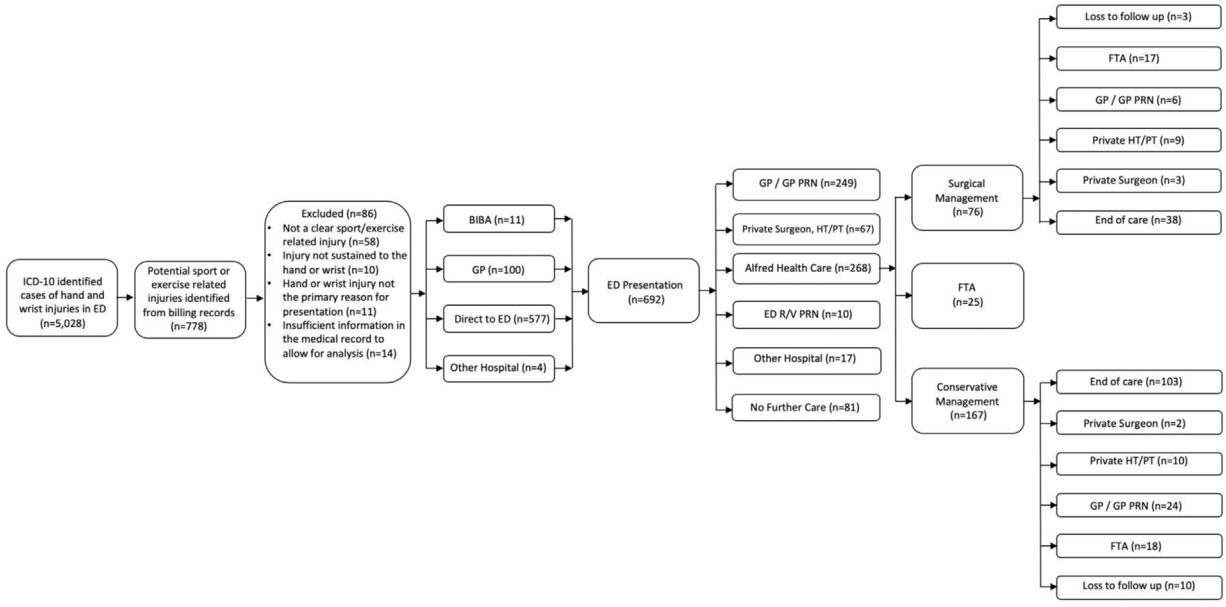

Fig. 1. Patient pathway.
Abv: BIBA: brought in by ambulance; GP: general practitioner; ED: emergency department; PRN: per registered need; HT: hand therapist; PT: physiotherapist; R/V: review; FTA: failed to attend.

Data analysis was performed using R studio and Microsoft Excel.

3. Results

A total of 692 patients, with a total of 761 individual zones of injuries (ZOI), who attended an ED within Alfred Health with an acute hand or wrist injury as a result of sport or exercise were eligible for inclusion in this study. This represents approximately 14% of all hand and wrist injury ED presentations during the data collection period.[11] Eighty-six cases were excluded following a full review of electronic medical records as they did not have a clear sport/exercise related cause of injury (n = 58); the injury was not sustained to the hand or wrist (n = 10); the hand or wrist injury was not the primary reason for presentation to the ED (n = 11); or there was insufficient information reported in the medical record to allow for adequate data extraction and analysis (n = 14) (refer Fig. 1). Demographic data are reported in Table 1.

A total of nineteen different sport and exercise categorises associated with injuries were observed (refer Table 1). Australian Rules Football (ARF) was found to be the most significant contributor to injuries (20.2%), followed by riding a bicycle (15.9%), basketball (11.8%) and soccer (known in European countries as football) (9.4%).

The patient care journey for all cases can be seen in Fig. 1. The mean days between the date of injury (DOI) and presentation to the ED was 1.14 [95% CI 0.82-1.46]. A total of seven patients represented to the ED following their initial presentation during their episode of care.

Seventy-five (27.9%) participants who were referred and attended for further management within Alfred Health (n = 243) received a different diagnosis by the specialist medical team to that documented in the ED (e.g. a missed fracture, incorrect interpretation of imaging, or substantially different anatomical location of zone of injury). When considering health profession and clinician training, registrars (who have at least two years medical training) and interns (during their twelve-month internship following graduation) were most likely to provide a primary diagnosis in the ED that was later revised by the specialist medical team (35% and 33% of all referrals to a specialist medical team respectively). Approximately 8% of patients saw a physiotherapist as their primary consultant within the ED, with 62% of these cases being referred on for specialist opinion (either a surgeon or hand therapist within Alfred Health or for private follow-up).

The location of all individual ZOI (n = 761) can be seen in Fig. 2. It should be noted that this includes all 692 cases, therefore, there is a risk that some cases may have a different diagnosis to that stated in the ED. Globally, most injuries were sustained to the little finger (n = 154) and/or the wrist (n = 150). When considering the 243 patients who attended one or more specialist outpatient appointments (medical or therapy), and had a confirmed diagnosis provided by a specialist, the most common primary type of injury was a fracture (n = 150), followed by a joint injury (n = 58) or tendon injury (n = 19) (refer Table S1).

For cases that required and attended outpatient appointments (n = 243), the median number of appointments with a surgeon (or Registrar/Resident Medical Officer) was 2 [IQR 1–3] (refer Table S1). Injuries that required surgical intervention resulted in a higher median number of medical appointments (n = 73; Mdn: 2 [IQR 2–4]) then conservatively managed injuries (n = 170; Mdn: 1 [IQR 1–2]).

The median number of therapy appointments delivered at the hospital by a hand therapist or physiotherapist for all injuries was 2 [IQR 0–4] (refer Table S1). Injuries that were surgically managed required a higher median number of therapy appointments (n = 76; Mdn: 4 [IQR 1.25–6]) than conservatively managed injuries (n = 167; Mdn: 2 [IQR 0–3]). It should be noted, however, that it is common practice for physiotherapists in the study setting to refer fractures externally for private follow-up which has the potential to lead to a skewed representation of the data results. For fractures that were managed by a hospital-based hand therapist (n = 83), the median number of appointments was 3 [IQR 2–5].

The combined total cost for treatment of all cases (n = 692) within Alfred Health was $790,325 (refer Table S2). Inpatient costs contributed the highest portion of total cost (n = 76; $354,984; 45%) followed by ED costs (n = 692; $239,611; 30%) and outpatient costs (n = 264; $195,730; 25%). The median cost per case for each treatment location was $278 [IQR $210 - $282] in the ED (n = 692), $3328

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Table 1
Demographics of included cases.

		n=	
Presentations		692	
Individual zone of injury		761	
Age (years)	Median [IQR]	25	[16–33.75]
		n=	*%*
Gender	Male	511	73.8%
	Female	181	26.2%
Hand Dominance	Left	32	4.6%
	Right	360	52.0%
	Not Stated	300	43.4%
Hand Injured	Left	360	52.0%
	Right	328	47.4%
	Bilateral	4	0.6%
Mechanism of injury	Athletics/Gymnastics/Dancing	22	3.2%
	Australian Rules Football	140	20.2%
	Ball Sport (Unspecified)	10	1.4%
	Baseball/Softball	6	0.9%
	Basketball	82	11.8%
	Bicycle	110	15.9%
	Cricket	38	5.5%
	Golf	3	0.4%
	Hiking/Horse Riding	4	0.6%
	Hockey/Ice Hockey	14	2.0%
	Martial Arts/Boxing	18	2.6%
	Netball	57	8.2%
	Racquet Sports	7	1.0%
	Rugby	24	3.5%
	Skateboard/Scooter/Rollerblading	52	7.5%
	Snow Sport	18	2.6%
	Soccer	65	9.4%
	Volleyball	5	0.7%
	Water Sports	17	2.5%
Occupation	Clerical and Administrative Workers	42	6.1%
	Community and Personal Service Workers	36	5.2%
	Labourers	7	1.0%
	Machinery Operators and Drivers	2	0.3%
	Managers	40	5.8%
	Not stated	185	26.7%
	Professionals	76	11.0%
	Retired	5	0.7%
	Sales Workers	22	3.2%
	Student	219	31.6%
	Technicians and Trades Workers	52	7.5%
	Unemployed	6	0.9%

[IQR $2242 - $6,416] in the inpatient setting (n = 76) and $630 [IQR $460 - $870] in the outpatient setting (n = 244). The median costs of treatment location and number of injuries for each sport and exercise category can be seen in Table S2.

Injuries sustained from riding a bicycle (n = 110) led to the largest overall costs ($173,076) and the highest ED and outpatient costs. Injuries sustained while playing ARF (n = 140) led to the second-largest overall costs ($161,538) and also the most cost accrued in the inpatient setting.

4. Discussion

Profile and cost data relating to acute hand and wrist injuries sustained as a result of sport and exercise in the Australian Healthcare system have been absent from the empirical literature to date. This study shows that these injuries represent approximately 14% of all hand and wrist injury ED presentations at one Australian hospital network in one financial year.[11] These injuries cost over AU$790,000 of direct healthcare costs within the one health network.

Male patients (74%) were disproportionally represented among the study sample. This finding, however, is not uncommon in the international literature for upper extremity injuries sustained from participation in sport or exercise such as soccer,[15,16] basketball,[16,17] volleyball,[16] or running.[16] Further, in a study that investigated the epidemiology of sport-related hand fractures (n = 1430) that 86% of observed cases were male.[4] This finding may be partially explained by the fact that in general Australian males aged between 15-17 years and 18-24 years have higher participation rates in sport and physical activity than females (85% and 70%; 76% and 67% respectively).[18] However, the difference between participation rates for individuals aged between 25-34, which contains the median age of our included cases (Mdn: 25 years [IQR 16–33.75 years]), is negligible. Our finding that only 9% of cases were aged over 45 years is consistent with the decrease in participation trends observed in Australia[18] and highlights the fact that individuals who sustain a sport or exercise-related hand or wrist injury are likely to be engaged in higher education or at the beginning of their economically productive years.

Australian Rules Football (ARF), a unique code of football widely played only in Australia, was the leading cause of injury for

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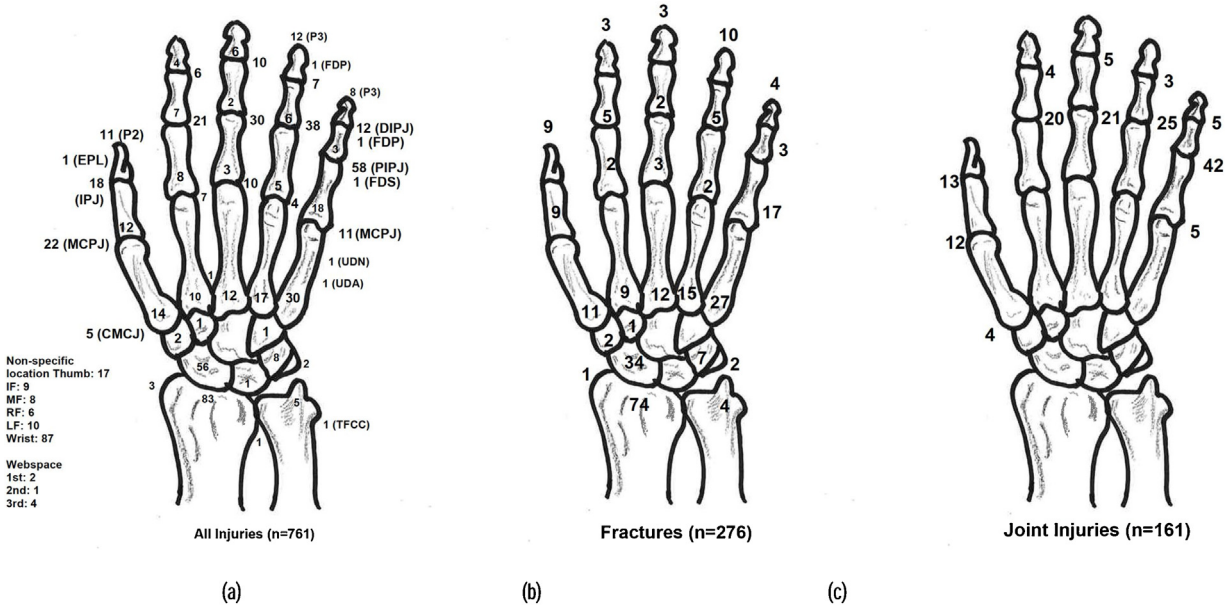

Fig. 2. Injury location (a) all injuries; (b) fractures; (c) joint injuries.
Abv: IF: index finger; MF: middle finger; RF: ring finger; LF little finger; CMCJ: carpometacarpal joint; MCPJ: metacarpophalangeal joint; IPJ: interphalangeal joint; EPL: extensor pollicis longus; FDP: flexor digitorum profundus; P1: proximal phalanx; P2: middle phalanx; P3: distal phalanx; DIPJ: distal interphalangeal joint; PIPJ: proximal interphalangeal joint; FDS: flexor digitorum superficialis; UDN: ulna digital nerve; UDA: ulna digital artery; TFCC: triangular fibrocartilage complex.

included cases. The sport, which is full contact, involves a mix of physical endurance (four 20-min quarters), high speed running, frequent changes of direction, jumping, sudden and forceful collisions, aggressive tackling as well as kicking and ball-handling skills.[19,20] Owing to its distinctive rules and physical demands, the sport exposes players to both unique and uncommon injuries compared to those sustained in other football codes (e.g. gridiron football played in the United States and Canada or Gaelic football played in the Republic of Ireland).

Published evidence pertaining to all injuries sustained playing ARF at a community level estimate that upper limb injuries account for between 13–33.9% of all ARF injuries[19,20] and hand and wrist account for approximately 8% of all injuries.[21] Further, hand fractures are the second most frequent injury, behind concussion.[22] Our finding that they account for one in five sport or exercise-related injuries at Alfred Health at the cost of AU$167,538 may have implications for potential health promotion, sports-safety or injury prevention strategies. This includes, but is not limited to, regulations surrounding ground conditions, and education or formal implementation of safety practices at a grassroots and amateur levels to ensure that the risk of injuries related to tackling and marking (i.e. catching the ball) are minimised. Further, strategies that aim to reduce the risk of misdiagnosis and exposure to further injury, such as the availability of health professionals trained in acute hand trauma,[19,23] should also be considered.

Injuries sustained from riding bicycles (n = 110) were the costliest mechanism of injury for cases included in this study, resulting in AU$167,538 of healthcare costs within the study setting. Causes included being struck by a car and environmental causes (e.g. potholes, road conditions, weather). This may have implications for potential health promotions strategies such as protected bike lanes or road safety campaigns[24]; however, research into their efficacy and cost-effectiveness is required.

A key finding of this study was the high percentage of cases that were discharged from the health service due to failing to attend (FTA) their final appointment (22% of all cases (n = 268); 22% of surgically managed cases (n = 76); and 11% of conservatively managed cases (n = 167)). Further, a third of cases (33%) had at least one or more recorded FTA during their patient care journey within Alfred Health. While at the higher end, this finding falls within the previously published FTA outpatient appointment data estimates.[25] Beyond the financial costs that FTA incur, they can also lead to inefficient use of facilities with unnecessary delays in the waiting times to assess or review other patients which can lead to poorer clinical outcomes.[26] Research focusing on reducing non-attendance has primarily focused on the effects of reminders (e.g. text messages which have been observed to have some effect[27]), with motivational effects underexamined. Further research should attempt to determine the best interventions, which decrease non-attendance rates with this population.

Another key finding of this study was that 27.9% (n = 75) of patients who were referred and attended for further management within Alfred Health (n = 243) received a revised diagnosis by the specialist medical team than what was provided in the ED. Thirty-one cases had missed or incorrect interpretation of medical imaging results, 33 had misdiagnosis/missed injuries, and 11 reported the incorrect anatomical location of the injury. This finding may be explained by a number of contributing factors including the lack of available imaging or delay in receiving radiology reports, inability to conduct a complete clinical examination due to pain or other patient related factors, or clinician experience at the time of ED presentation. While it is difficult to ascertain the exact reasons due to the retrospective design of this investigation, our finding that registrars and interns were most likely to provide a diagnosis that was later revised by the specialist medical team is consistent with previously published studies.[28,29]

There are several limitations that must be considered in the context of this investigation. First, caution must be taken when generalising the findings to the Australian population as data was collected from a single-centre in the state of Victoria. For example, the finding that ARF was the sport leading to the most injuries is likely due to its popularity in Victoria. It is likely that if a similar study was conducted in other states of Australia (e.g. New South Wales where Rugby League/Union is the most popu-

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lar form of football), findings would differ. Further, it should be noted that direct medical costs associated with emergency medical treatment can vary for health services within and between the different states and territories of Australia. Second, although we present the costs accumulated by Alfred Health, we did not include indirect costs that occur due to loss of productivity (estimated to be between 64.5–68% of total costs),[30] other costs borne by the individuals themselves or the costs that may have been incurred at other health services outside of the study setting. To present a complete estimate of the burden of these injuries, studies from the societal perspective (which include medical, morbidity, mortality, transportation and non-medical costs) are recommended.[13] Additionally, we did not capture costs that occurred prior to ED presentation (e.g. GP) or after (e.g. privately funded practitioners). Finally, it is likely that our cost calculations are underestimates due to factors such as cost-shifting, data entry error, or other miscellaneous causes. In an attempt to decrease underestimation, outliers were closely inspected alongside medical records to determine if under- or over-costing had likely occurred (e.g. the number of resources used compared with cost estimate available).

Despite these limitations, our study had several notable strengths. First, we had a large database of ED presentations collected over a one-year period that allowed for a detailed analysis. Second, we have addressed an important void in literature both in Australia and internationally regarding the demographics, costs and outpatient resources associated with hand and wrist injuries sustained from sport or exercise.

5. Conclusions

Acute hand and wrist injuries sustained from sport and exercise have the potential to contribute a significant burden on the Australian public health system. Our study has shown that these injuries result in substantial direct healthcare costs at one major public health service over one year.

Author contributions

Author LR conceived the study, designed the methodology, collected and analysed the data.

Author TB and LOB supervised the conduct of the study, data collection and analysis.

Author LR drafted the manuscript, and Author TB and LOB contributed substantially to its revision.

Author LR takes responsibility for the paper as a whole.

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Appendix A

Table A1
ICD-10 Codes used for case identification.

ICD-10 Code	Description
S609	Superficial injury of wrist and hand, unspecified
S619	Open wound of wrist and hand part, part unspecified
S628	Fracture of other and unspecified parts of wrist and hand
S6300	Dislocation of wrist, part unspecified
S6310	Dislocation of finger, part unspecified
S6350	Sprain and strain of wrist, part unspecified
S637	Sprain and strain of other and unspecified parts of hand
S649	Injury of unspecified nerve at wrist and hand level
S659	Injury of unspecified blood vessel at wrist and hand level
S669	Injury of unspecified muscle and tendon at wrist and hand level
S678	Crushing injury of other and unspecified parts of wrist and hand
S684	Traumatic amputation of hand at wrist level
S689	Traumatic amputation of wrist and hand, level unspecified
S697	Multiple injuries of wrist and hand
S698	Other specified injuries of wrist and hand
S699	Unspecified injury of wrist and hand

Table A2
Included cost components.

Cost location	Included cost components
Emergency Department Costs	Allied Health Emergency Department (including medical) Imaging Pathology Pharmacy
Inpatient Costs	Allied Health Imaging Medical (non-surgical) Medical (surgical) Other Pathology Pharmacy Theatre Ward/Nursing
Outpatient Costs	Hand Therapy (Occupational Therapy / Physiotherapy) (Unit cost price (2015) $80) Speciality Medical Services (Plastic Surgery or Orthopaedics) (Unit cost price (2015) $280)

Appendix B. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.jsams.2020.01.007.

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