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Incidence, mechanism and risk factors for injury in youth rock climbers

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INCIDENCE, MECHANISMS AND RISK FACTORS FOR INJURY IN YOUTH ROCK CLIMBERS

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ABSTRACT

Background: Rock climbing participation has grown globally in recent years, and the sport was officially recognized by the International Olympic Committee in 2010. The epidemiology of climbing injuries in adults has been examined, but few studies have investigated injury in youth climbers.
Objective: To examine incidence, mechanisms, and risk factors for injury in recreational and elite sport climbers and boulderers aged 11–19 years.
Study design: Cross-sectional
Methods: Youth (n=116) were recruited from climbing facilities across Alberta, Canada. Participants completed an anonymous questionnaire from October 2012 to March 2013. Climbing injury incidence proportions (IP) and incidence rates (IR) were calculated. Odds ratios (OR) with corresponding 95% confidence intervals (CI) were estimated for possible risk factors.
Results: The injury IR was 4.44 injuries/1000 climbing hours (95% CI; 3.74 to 5.23). Sprains (27%) and strains (26%) were the predominant injury types, and repetitive overuse, the primary mechanism of injury (42%). Hands and fingers were the most commonly injured locations (21%). Exploratory analyses showed three risk factors for injury: older age (15–19 versus 11–14 years) (OR=11.30, 95% CI; 2.33 to 54.85), injury in a sport other than climbing (OR=6.46, 95% CI; 1.62 to 25.68), and preventive taping (OR=5.09, 95% CI; 1.44 to 18.02).
Conclusions: Injury risk is high in youth climbers. Findings are consistent with reported rates, types, and mechanisms in adults. Modifiable risk factors warrant further investigation to inform development of injury prevention strategies, targeting high-risk climbers including adolescents and those with previous injury.

What are the new findings?
• Findings demonstrated a high climbing injury incidence rate of 4.44 injuries/1000 climbing hours (95% Confidence Interval [CI]; 3.74, 5.23) in young climbers, a rate similar to ice hockey and soccer in the same age group. • Hand, finger and shoulder ligament sprains and muscle or tendon strains were found to be the most common injuries. • Repetitive overuse was reported as the primary mechanism of injury followed by falls. • Older age (15–19-year-olds), injury in a sport other than climbing, and preventive taping were shown to be significant risk factors for injury.

How might this impact on clinical practice in the near future?
• Healthcare providers will require familiarity with climbing injuries in order to recognize and manage these injuries as this sport continues to grow in global popularity. This growth will inevitably result in a greater number of injuries and consequent time loss from activity. • High injury incidence rates, especially of overuse injuries and fall-related injuries will increase the long-term burden on the healthcare system. • Knowledge around the main mechanisms of injury and possible risk factors for injury will lead to the development of injury prevention measures that clinicians can begin to implement in their practice.

INTRODUCTION

Rock climbing has been steadily gaining popularity worldwide, both as a recreational activity and as a competitive sport. Climbing includes a variety of disciplines that utilize unique movement forms, resulting in distinct injury patterns. Sport climbing is a discipline in which routes are normally a maximum of 30 metres in height. The climber is attached to a rope that is clipped into permanent bolts spaced intermittently from the bottom up (lead climbing), or anchored at the top of the climb (top roping). This allows climbers to incur frequent falls safely. Bouldering, however, uses large crash mats instead of ropes to protect climbers from falls, as "boulder problems" are usually short and low to the ground. Bouldering allows climbers to practice difficult and powerful moves repeatedly. Both disciplines are performed both outdoors on rock and indoors on artificial holds and surfaces.

Previous research has focused on injuries sustained in traditional rock climbing, ice climbing, mountaineering, and alpine settings in adult participants.[1–5] Injuries sustained in these activities consist largely of trauma resulting from falls or overhead rock fall, injuries from weather (e.g., frostbite), negative altitude effects, with some mention of training-related injuries.[2,6] The existing studies involving sport climbers and "boulderers" report high injury rates ranging from 103 injuries/100 participants/year to 137 injuries/100 participants/year, and 4.2 injuries/1000 climbing hours in adult climbers.[7–9] There is a paucity of epidemiological research examining injuries and risk factors in youth climbers specifically.[10–12] Existing studies are mostly case reports or focused on one single type of injury (e.g., epiphyseal fractures, finger injuries).[10–14] Greater knowledge regarding injury patterns and risk factors for youth climbers would help to inform the development of injury prevention strategies in this population.

The purpose of this study was to examine injury rates, types, mechanisms, and risk factors for injury in youth who participate in recreational and elite sport climbing and bouldering.

METHODS

Study Design

This was a cross-sectional study, based on the completion of an anonymous questionnaire, and was approved by the Conjoint Health Research Ethics Board of the University of Calgary (Ethics ID 24718).

Participants

An estimated target sample size of 206 participants was calculated. The questionnaire was distributed to recreational and elite youth climbers at ten indoor climbing facilities in Alberta, Canada from October 2012 to March 2013. This time frame encompassed most of the indoor competitive climbing season. Participants were males and females ages 11–19 years. Written consent was obtained from participants and parents/guardians (if less than 18 years). Participants were recruited from competitive junior teams, recreational programs, lessons, and workshops. In addition, convenience sampling was conducted at two youth competitions. Subjects were classified as recreational or elite as per the inclusion criteria below.

Inclusion criteria:

1. Recreational: Participation in sport climbing or bouldering at a climbing facility in Alberta, and participation in sport climbing or bouldering at least once per month during the previous year.
2. Elite: Participation in competition climbing during the 2012-2013 competition season and for minimum two years prior, or participation in an international competition during the previous 12 months.

3. Elite: Membership in Competition Climbing Canada/Competition d'Escalade Canada (CEC).

Data collection procedure

Study Questionnaire

Participants completed the questionnaire either online or in paper copy. Demographic information, including climbing experience, discipline (i.e., bouldering or sport climbing), and venue (i.e., outdoors or indoors), was collected. The questionnaire included items regarding exposure time (e.g., hours per day, days per week, months per year), injury types, anatomical locations, and mechanisms of injury incurred in the previous 12 months. The questionnaire was face validated through interviews with researchers, climbers, parents, coaches, physicians, physiotherapists, and one occupational therapist (n=20).

Primary analyses

The primary outcome measure was climbing injury, defined as any physical complaint that resulted from sport climbing or bouldering, indoors or outdoors, irrespective of the need for medical attention or time loss from climbing activities. This definition was adapted from the consensus statement on injury definitions and data collection procedures in studies of football injuries,[15] and from the definition used by the International Mountaineering and Climbing Federation (UIAA) Medical Commission Injury Classification for Mountaineering and Climbing Sports, modified for sport climbing and bouldering.[16] Injuries requiring medical attention and injuries resulting in time loss from full climbing participation were also calculated. Time-loss injury was categorized according to severity using groups defined by Fuller et al.: Slight injury (no time loss), minimal (1–3 days), mild (4–7 days), moderate (8–28 days), severe (>28 days), and career ending.[15]

Exploratory analyses

Potential intrinsic risk factors examined were climbing level (i.e., recreational or elite), age, sex, height, weight, the difficulty at which participants climbed using the Yosemite Decimal System converted to the standardized metric scale, injury in other sports, and risk-taking behaviours (i.e., smoking tobacco, alcohol consumption, seatbelt non-use) that have been shown to be related to youth injury in sport.[17] Potential extrinsic risk factors included socioeconomic status (SES), specific discipline of climbing, participation in other sports, helmet use, preventive taping, use of a cool-down, and climbing exposure hours collected for both indoor and outdoor climbing. Exposure hours were also used to estimate injury incidence rates (IR).

Statistical Methods

STATA v.12 (Statacorp, College Station, TX) was used to perform statistical analyses. Injury types, mechanisms, and anatomical locations were described using means or medians. The primary analysis included univariate logistic regression analysis (offset for exposure hours) to examine the difference in injury risk in recreational climbers compared to elite climbers. This study was powered to detect a clinically important difference in injury incidence proportion of 20% between elite and recreational groups. Exploratory univariate logistic regression analyses (offset for exposure hours) were used to assess potential risk factors for injury, chosen for this analysis based on previous literature.[3,4,6–10,12,14,17–25] Risk factors for time-loss injury were also examined for comparison purposes. A multivariate logistic regression analysis offset for exposure hours was conducted for co-variables that demonstrated a 20% difference in crude odds ratio (OR) with 95% confidence intervals (CI) and a significance level of 5% (α=0.05). This percentage was chosen arbitrarily as a reasonable cut-off for clinical importance. Confounding and effect modification were examined for co-variables.

RESULTS

Participants

Sixty-two competitive and 223 recreational climbers were approached (N=285). Of these, 126 climbers (44%) consented to participate, and 116 (41%) completed the questionnaire (Figure 1).

Based on the inclusion criteria, participants were categorized as elite (n=50) or recreational (n=66). Table 1 summarizes participant characteristics.

Table 1. Baseline characteristics for recreational and elite climbers

Characteristic	Elite (n=50)	Recreational (n=66)
Sex (male, female)	31 males (62%) 19 females (38%)	25 males (38%) 41 females (62%)
	Mean (95% confidence interval)	
Age (years)	15.46 (14.84, 16.08)	14.12 (13.53, 14.71)
Height (cm)	166.95 (163.40, 170.49)	158.90 (155.36, 162.43)*
Weight (kg)	53.63 (50.29, 56.96)	47.23 (44.25, 50.22)
Body mass index (kg/m^2)	19.00 (18.31, 19.69)	18.30 (17.67, 18.94)*
Climbing participation (hours/week)	13.40 (11.87, 14.93)	6.91 (5.71, 8.11)
	Median (range)	
Socioeconomic status (0-9 on Family Affluence Scale)	8 = high affluence (4, 9)	8 = high affluence (2, 9)
Sport climbing grade: Yosemite Decimal System (YDS); Metric scale	5.12a (5.10a, 5.13c); 8.24 (7.96, 8.50)	5.10d (5.8, 5.12c)**; 6.01 (5.33, 6.69)**
Bouldering Grade (Hueco)	V5/6 (V1, V10)***	V3 (V1, V12)****
	Number of climbers (%)	
Participate in outdoor climbing	36 (72%)	18 (27%)
Participate in indoor climbing	50 (100%)	66 (100%)
Participate in sport climbing	50 (100%)	57 (86%)
Participate in bouldering	46 (92%)	66 (100%)

*2 missing values excluded from mean
**6 participants unfamiliar with the YDS grading scale; excluded as missing values
***10 participants unfamiliar with the Hueco grading scale; excluded as missing values
****35 participants unfamiliar with the Hueco grading scale; excluded as missing values

Climbing Participation

The mean amount of time reported for indoor climbing was 7 hours/week, 9 months/year. Overall, less time was spent outdoor climbing (mean 6 hours/week, 3 months/year). Elite climbers spent more time climbing than recreational climbers (Table 2).

Table 2. Participation hours per week by venue for recreational and elite climbers

Climbing venue	Elite		Recreational	
	Mean hours/week (95% Confidence Interval [CI])	Number of participants	Mean hours/week (95% CI)	Number of participants
Indoors (n=116)	8.46 (7.75 to 9.17)	50	5.38 (4.68 to 6.08)	66
Outdoors (n=54)	6.68 (5.56 to 7.79)	36	5.61 (3.89 to 7.33)	18

Climbing Injury Incidence Rates and Incidence Proportions

Seventy-three (63%) participants sustained at least one new climbing injury in the 12 months prior to the study, including those reporting "pain or discomfort". Thirty-six (31%) reported multiple injuries. The total number of injuries incurred was 142, resulting in an IP of 122/100 participants/year (95% CI 98 to 147). The overall IR was 4.44/1000 participation hours (95% CI 3.74 to 5.23).

Forty-one (82%) elite climbers sustained 84 injuries [IP = 168 /100 participants/year (95% CI 134 to 208)], compared with 32 (48%) recreational climbers who sustained 58 injuries [IP = 88/100 participants/year (95% CI 67 to 114)]. The IR for elite climbers was 4.27/1000 hours (95% CI 3.45 to 5.29), and 4.71 injuries/1000 climbing hours (95% CI 3.64 to 6.09) for recreational climbers.

Time-loss injuries

Overall, 109 (77%) injuries resulted in at least one day of time loss from climbing [IP = 94/100 participants/year (95% CI 72 to 116); IR = 1.81/1000 hours (95% CI 1.38 to 2.34)]. The median amount of time loss was 14 days (interquartile range; 7, 61), including ongoing injuries where participants had not yet returned to full activity. Figure 2 shows the proportions of injuries incurring time loss from climbing, according to severity groups.

Medically treated injuries

Seventy-six (54%) participants received medical attention [IP = 66/100 participants/year (95% CI 46 to 85); IR = 2.62/1000 hours (95% CI 2.09 to 3.25)], including first aid, treatment by an emergency medical technician/paramedic, physician, physiotherapist, chiropractor, athletic therapist, massage therapist, or "other" treatment (e.g., acupuncture, osteopathic manual therapy, regular icing of the injury). Physiotherapy was the most common treatment reported (33%).

Injuries by climbing venue and by discipline

Tables 3 and 4 describe the proportion of injuries sustained by climbing venue (i.e., indoor or outdoor) and discipline (i.e., sport climbing or bouldering).

Table 3. Injury incidence proportion (IP) and incidence rate (IR) by venue

Venue of sustained injury	IP as injuries /100 participants /year (95% Confidence Interval)	IR as injuries/1000 hrs. (95% Confidence Interval)
Indoor	89 (74, 106)	4.31 (3.59, 5.13)
Outdoor	6 (2, 11)	2.94 (1.27, 5.79)
Both indoor and outdoor	6 (2, 11)	N/A
Total	N/A	4.44 (3.74, 5.23)

Table 4. Injury incidence proportion (IP) by discipline

Discipline during sustained injury	IP as injuries /100 participants /year (95% Confidence Interval)
Sport Climbing (%)	33 (24, 44)
Bouldering (%)	58 (46, 72)
Both sport and bouldering (%)	5 (2, 10)
Other discipline*	4 (2, 9)

*"Other discipline" reported by participants included strength training and conditioning for climbing, setting an indoor climbing route, and injuries originating elsewhere but aggravated by climbing.

Injury Characteristics

Injury types are summarized in Table 5. There were 85 self-reported injuries, 22 (26%) of which were re-injuries. These did not include other "pains or discomforts" as these were not classified by injury type or mechanism. "Pains or discomforts" were described by open answer (e.g., low back pain, general pain in a specific area during climbing). The predominant self-reported injury type was ligament sprain, followed by muscle or tendon strain. Of the 142 injuries and "pains or discomforts," the highest proportions of complaints were to the hands and fingers (21%), followed by shoulders (15%), knees (9%) and ankles (9%).

Table 5. Self-reported climbing injury by type

Injury type	Frequency (%)	IR/1000 hrs. (95% Confidence Interval)
Ligament sprain	23 (27)	0.72 (0.46, 1.08)
Muscle/tendon strain	22 (26)	0.69 (0.43, 1.04)
Tendonitis	11 (13)	0.34 (0.17, 0.62)
Joint swelling/inflammation	7 (8)	0.22 (0.09, 0.45)
Abrasion	3 (4)	0.09 (0.02, 0.27)
Concussion	3 (4)	0.09 (0.02, 0.27)
Cut/scrape/skin flapper	3 (4)	0.09 (0.02, 0.27)
Dislocation/subluxation	3 (4)	0.09 (0.02, 0.27)
Fracture	3 (4)	0.09 (0.02, 0.27)
Other*	3 (4)	0.09 (0.02, 0.27)
Unspecified overuse injury	2 (2)	0.06 (0.01, 0.23)
Unspecified nerve injury	2 (2)	0.06 (0.01, 0.23)
Bruise	0 (0)	0
Bleeding (i.e., nose bleed, etc.)	0 (0)	0
Total	85 (100)	2.66 (2.12, 3.29)

*"Other" injury types were described as "disc bulge," hypermobility, and hyperextension.

The most commonly reported mechanism of injury was repetitive overuse, followed by falls, and those incurred during strenuous moves (i.e., any physically demanding climbing move). Most repetitive overuse injuries involved the upper body, while most fall-related injuries involved the lower extremity (Figure 3).

Risk Factors

Preliminary univariate analyses, summarized in Table 6, indicated several potential risk factors to include in the multivariate model. Results from univariate analyses for time-loss injury yielded largely the same findings as for all climbing injuries, with the exception of height, weight, and alcohol consumption.

Table 6. Exploratory univariate analyses

Risk factors	IR/1000 hrs. (95% Confidence Interval [CI])	OR adjusted for climbing participation hours (95% CI)	Time-loss injury OR adjusted for climbing participation hours (95% CI)
Climbing level			
Recreational	4.71 (3.64, 6.09)	1	1
Elite	4.27 (3.45, 5.29)	2.43 (0.88, 6.72)	2.43 (0.96, 6.12)
Sex			
Female	5.56 (4.49, 6.88)	1	1
Male	3.44 (2.66, 4.45)	0.97 (0.42, 2.23)	0.81 (0.37, 1.77)
Age group			
11–14 years	3.49 (2.64, 4.62)	1	1
15–19 years	5.18 (4.22, 6.34)	4.45 (1.65, 11.99)*	5.39 (2.20, 13.22)*
Height			
Lower 75%	4.91 (4.04, 5.97)	1	1
Top 25th percentile by age group	3.61 (2.67, 4.89)	0.79 (0.32, 1.96)	1.03 (1.00, 1.07)
Weight			
Lower 75%	4.97 (4.12, 5.99)	1	1
Top 25th percentile by age group	3.24 (2.29, 4.58)	0.53 (0.20, 1.41)	1.05 (1.02, 1.09)*
SES			
Low-medium high affluence (0–7 on the Family Affluence Scale [FAS])	4.76 (3.69, 6.14)	1	1
High affluence (8–9 on the FAS)	4.23 (3.42, 5.25)	1.15 (0.50, 2.65)	0.98 (0.44, 2.15)
Sport climbing grade (n=101; missing 15 values)			
Yosemite decimal system (YDS): 5.8–5.11a Metric: 5.66–7.33	3.74 (2.69, 5.21)	1	1
YDS: 5.11b–5.13c Metric: 7.33–9.66	4.60 (3.77, 5.61)	2.86 (1.02, 7.99)*	2.45 (0.94, 6.36)
Participation in other sports			
No	5.39 (3.87, 7.50)	1	1
Yes	4.20 (3.47, 5.07)	1.06 (0.41, 2.71)	0.85 (0.34, 2.08)

Injury sustained in other sports within the previous year			
No	3.47 (2.70, 4.45)	1	1
Yes	5.63 (4.53, 7.00)	3.88 (1.55, 9.72)*	4.56 (1.84, 11.29)*
Any climbing helmet use within the past year			
No	4.37 (3.24, 5.89)	1	1
Yes	4.47 (3.67, 5.44)	2.61 (1.10, 6.24)*	2.33 (1.02, 5.31)*
Use of taping as a preventive measure			
No	3.78 (2.94, 4.84)	1	1
Yes	5.14 (4.13, 6.40)	3.24 (1.30, 8.06)*	1.52 (0.69, 3.39)
Use of a cool-down after climbing			
No	4.91 (3.85, 6.26)	1	1
Yes	4.11 (3.28, 5.13)	0.62 (0.26, 1.51)	0.45 (0.20, 1.02)
Other risk-taking behaviours:			
No	4.55 (3.72, 5.56)	1	1
Yes	4.23 (3.18, 5.63)	1.30 (0.39, 4.32)	1.06 (0.38, 2.98)

*Statistically significant at $p<0.05$

Based on multivariate logistic regression (Table 7), climbers aged 15 to19 years were at 11.3 times greater risk of injury (95% CI 2.33 to 54.85) than those aged 11 to 14 years. Compared with those who had no other injuries, the odds of injury were 6.46 times greater (95% CI 1.62 to 25.68) for those who had also sustained an injury from another sport. Finally, the odds of injury for those who used preventive taping were 5.09 times greater (95% CI 1.44 to 18.02) than those who did not. Age group and sport climbing grade were not found to modify the relationship between injury and climbing level. There was no evidence of confounding by other co-variables.

Table 7. Exploratory multivariate logistic regression predicting climbing injury

Risk factors	Adjusted OR (95% Confidence Interval)
Climbing level	
Recreational	1
Elite	2.19 (0.56, 8.50)
Age group	
11-14 years	1
15-19 years	11.30 (2.33, 54.85)*
Weight	
Lower 75%	1
Top 25th percentile by age group	0.37 (0.10, 1.35)
Sport climbing grade (n=101; missing 15 values)	
5.8-5.11a	1
5.11b to 5.13c	1.57 (0.39, 6.41)
Injury sustained in other sports within the previous year	
No	1

Yes	6.46 (1.62, 25.68)*
Any climbing helmet use within the previous year	
No	1
Yes	1.27 (0.36, 4.47)
Use of taping as a preventive measure	
No	1
Yes	5.09 (1.44, 18.02)*
Use of a cool-down after climbing	
No	1
Yes	1.09 (0.29, 4.08)
Other risk-taking behaviours: Alcohol consumption	
No	1
Yes	0.39 (0.06, 2.50)

*Statistically significant at $p<0.05$.

DISCUSSION

This is the first study to examine incidence rates, injury types, mechanisms of injury and risk factors for injury in recreational and elite youth climbers.

Sport climbing and bouldering are highly male-dominated at the elite level. Findings in the present study appear to be consistent with this disparity, though we cannot know if a similar proportion of male and female climbers declined in each category. The mean age of elite climbers was older than recreational climbers, explaining greater mean height and weight as well as the higher grades at which this group climbed (i.e., higher skill level).

The injury IP we found was high (122 injuries/100 participants/year), but similar to that for adult sport climbers [7] and boulderers.[20] However, as exposure is critical in examining the injury risk, the injury IR was calculated and found to be 4.44 injuries/1000 climbing hours. This rate is high and similar to the 4.2 injuries/1000 hours reported by Backe et al.;[9] it is similar to the injury IR reported in youth ice hockey (4.13 injuries/1000 participation hours),[26] and slightly lower, though comparable, to that reported in youth soccer following the same injury definition with clinical verification of injuries in a prospective design (5.59 injuries/1000 participation hours).[21]

The IR for medically treated injuries was 2.62 injuries/1000 climbing hours, while for time-loss injury was 1.81 injuries/1000 climbing hours. The distribution of injuries by time loss in this study suggests greater time loss than previously reported in youth ice hockey and other sports.[21,22,26] This is likely due to the nature of these climbing injuries, a high proportion of which were ongoing overuse injuries or injuries from traumatic falls. It is possible that there was an underreporting of minor injuries due to negative attitudes around injury, as well as related to recall bias, resulting in an overrepresentation of time-loss injuries.

Sprains and strains were the most commonly occurring injuries in these young climbers, followed by tendonitis. "Repetitive overuse," being any injury caused by repeated movements or stress and usually beginning with an insidious onset, was found to be the most commonly self-reported mechanism of injury, followed by fall-related injuries. However, it is unknown to what extent there was consistent interpretation among participants as to the meaning of "repetitive overuse". The highest proportion of injuries occurred in hands, fingers, and shoulders. Stratifying by mechanism of injury, repetitive overuse injuries occurred predominantly in the upper extremities. This is consistent with previous research involving adult climbers in which overuse injuries, sprains, and strains to the upper body were found to be the most common.[6,8,10,18,20,23,27] The high proportion of fall-related injuries (32%) reported in the present study were mainly lower extremity injuries, and they accounted for 50% of the knee and ankle

injuries reported. Neuhof et al. reported a similar proportion of 39.9% for fall injuries, and Josephsen et al. reported that 23% of injuries occurring outdoors and 50% of injuries occurring indoors resulted from falls.[7,18]

Examination of the crude and exposure hours-adjusted ORs supports evidence that the risk of injury increases with participation hours in sport.[22] The results of the multivariate logistic regression identify three potential risk factors for injury: being 15-19 years old, having had an injury in another sport, or using preventive taping.

The wide confidence interval for the OR reported for the older age group may be due to the low number of participants in this group with the combination of variables in the multivariate model. Injury in other sports has not been previously examined as a risk factor for climbing injuries. It is uncertain whether this finding is related to physiological factors, the amount of exposure time to sport in general, risk behaviours, or other variables. The temporal association between "other sport injury" and "climbing injury" remains unclear in the context of this cross-sectional study; however, sport injury literature demonstrates that previous injury is a predictor of subsequent injury.[22,24,28] Preventive taping was used by 41% of participants, and in this study, was found to be a marker of susceptibility to injury. This result was contrary to previous findings by Josephsen et al. who found that finger and wrist taping in adults decreased the risk of injury.[7] Our result may be due to the fact that climbers who sustained previous injuries or who were injured used taping as a preventive measure for re-injury. Unfortunately, in a cross-sectional design the temporal relationship cannot be established. Similarly, those participants already at a higher risk of injury (e.g., older, elite climbers) may use more tape, causing taping itself to be indicative of a higher risk of injury. Lastly, these results may be explained by risk compensation, previously studied in several sports including skiing and snowboarding.[29] In the context of youth climbing, it could be argued that individuals who tape may engage in more aggressive or riskier climbing behaviour. Further research is needed to prospectively examine this relationship.

Although this multivariate analysis was exploratory and underpowered to reach conclusive results, it did introduce potentially clinically significant findings that may inform future studies.

Limitations

Cross-sectional studies are subject to limitations inherent in their design. Namely, it is not always possible to establish temporal relationships between risk factors and injuries.

Selection bias is possible in this study, as injured climbers may not have been attending indoor climbing facilities, where sampling took place, due to their injury.

Self-report designs are subject to potential self-diagnosis. Responses were subjective and injuries were not always diagnosed by a medical practitioner. To mediate this problem, injuries were objectively categorized by anatomical location and mechanism. Recall bias was possible, leading to under-reporting of minor injuries and comparative overrepresentation of more memorable traumatic injuries. This may explain the high proportion of medically treated and time-loss injuries. However, given that the largest proportion of injuries in this study were non-acute overuse injuries, the effect of recall bias is unclear.

Power for this study was limited, as the target sample size of 206 was not achieved. Though the anticipated compliance rate was 70%, only 116 of 285 climbers approached returned a questionnaire (41%). Emery et al. reported compliance rates for their cross-sectional study as low as 41% for schools requiring signed parental consent.[22] This may have been the reason for low compliance in this study. However, given that the effect size found was much larger than expected (80% difference based on elite and recreational IPs), a statistically significant and clinically relevant difference was found.

The questionnaire was completed throughout the competitive season, and it is possible that this varying timing may have affected the reporting or recall of injuries. However, as injuries from the previous one year were captured, this did encompass both one full competitive season and one full off-season for all participants.

The small outcomes and uneven clusters limited our ability to control for cluster. This study was not powered for a multivariate analysis and thus analyses examining risk factors were exploratory.

CONCLUSIONS

This is the first study to examine injury incidence rates, mechanisms of injury, and risk factors for injury in youth climbers. The overall climbing injury incidence rate was high. Hand, finger, and shoulder ligament sprains and muscle strains were the most common injuries. Repetitive overuse was the primary mechanism of injury followed by falls. The results of this study indicate that adolescents (15–19 years) are at a greater risk of injury than younger adolescents (11–14 years). Youth who have been injured in a sport other than climbing and those who use preventive taping may also have a greater risk of injury.

Climbing injury research will benefit from future prospective cohort studies to establish temporal relationships between injuries and risk factors. Further examination of risk factors observed in this analysis, as well as additional modifiable potential risk factors is warranted to inform the development of injury prevention strategies.

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