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Manuscript title: Epidemiology of sport climbing injuries caused by a climbing fall among
climbers of the French Federation of Mountain and Climbing

Running title: Sport climbing fall-related injuries

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ABSTRACT

BACKGROUND: Fall-related injuries (FRIs) are the most severe sport climbing injuries.

The main objective of this study was to measure FRI prevalence and risk factors in a representative sample of climbers of the French Federation of Mountain and Climbing.

The second objective was to explore FRI mechanisms.

METHODS: 3919 climbers aged 16+ participated in this study. They were invited to fill out an online questionnaire where they reported sociodemographics, sport-related characteristics and whether they had sustained an FRI in the past 12 months (12-FRI), and over their entire career (ALL-FRI). The mechanisms of 12-FRI were asked for.

Multivariable logistic regression analyses were performed to evaluate the association between sport-related characteristics and FRI.

RESULTS: 9% of the participants reported a 12-FRI and 29% an ALL-FRI. No statistically significant effect of sex, context of climbing, or onsight level was observed on 12-FRI. Climbers with 0-3 years of experience (YE) were 1.7 (95% CI=1.2-2.6) and 3.6 (95% CI=2.2-6.3) times more likely to have sustained a 12-FRI compared with those with 5-8 YE and 14-23 YE, respectively. An interaction effect was found between YE and onsight level. Among climbers with 0-8 YE, those with a higher onsight level had a higher risk of 12-FRI. Natural falls, unexpected falls and static belaying were the most commonly reported 12-FRI mechanisms.

CONCLUSIONS: These results highlight that future FRI prevention programs should target as a priority inexperienced climbers who have progressed rapidly. Climbers should

be taught as a priority (is) to stay focused while belaying even in the least difficult passage, and (ii) to belay dynamically.

Key words: Accidents; Athletic Injuries; Accident Injury

ACCEPTED AUTHOR MANUSCRIPT

Introduction

Sport climbing is rapidly growing in popularity. In the United Kingdom, the largest climbing association (British Mountaineering Council) has grown from about 26,000 members in 2001 to over 84,000 in 2018.^{1,2} Similarly, in France, the French Federation of Mountain and Climbing (FFME) has grown from 53,000 in 2000 to 110,000 in 2018.^{3,4}

Sport climbing is characterized by the use of bolted fixed protection on vertical wall ranging from 15 to 45m in most cases. In indoor climbing, typical wall height ranges from 13 to 18m. This height range is the standard for international competition.⁵ More importantly, in outdoor climbing, crags can reach 40m height. Sport climbers' objective is to reach the top of the route without falling and only using footholds and handholds without the help of additional gear to rest or to gain altitude during the climb. Climbers are secured by a belayed dynamic rope they have attached to their harness. During the ascent, they pass the rope through a quickdraw which is itself fixed on an anchor pre-fixed on the wall. In the event of a fall, the belayer is in charge of stopping the climber's fall with appropriate technical skills and equipment.

Falls are frequent and mostly harmless given the recommended positioning during a fall.^{6,7} They are responsible for only 7 to 10% of all injuries sustained by climbers.^{8,9} However, most acute injuries have been experienced following a fall.¹⁰ More precisely, despite the low prevalence of fall-related injury (FRI), more than 60% of climbing injuries treated in emergency departments have been caused by a climbing fall.¹¹⁻¹³ In addition, some falls can result in very severe injuries or fatalities. Such accidents are rare but they do happen.^{10,14} These results show the important contribution of climbing falls to moderate to very severe injury.

A fall can also cause injury among belayers, for instance due to violent impact of the belayer onto the wall when catching the climber's fall.¹⁵ On the ground, risks are also

represented by irregular terrains and the presence of obstacles such as trees, tree stumps or rocks. In that case, an inappropriate anticipation by the belayer may result in hitting these obstacles. However, the etiology, risk factors and mechanisms leading to an FRI remain complex and little understood as only a few studies have specifically studied this subject.⁶ Most of the sport climbing epidemiology literature has focused on acute or overuse injuries not provoked by fall without specifically considering FRI.^{16–19} Similarly, studies that have identified the greater severity of FRI were not population-based.^{11,12} Thus, it is difficult to determine which climber population is the most vulnerable according to their age, sex, years of experience, hours of participation, or level of climbing. Finally, to our knowledge, no study has explored the diversity of mechanisms that could lead to FRI.

The main purpose of this study was to measure FRI prevalence and risk factors occurring in single-pitch sport climbing routes (i.e. bouldering and traditional climbing excluded) in a representative sample of French climbers who were members of the FFME. The second objective was to explore FRI mechanisms. These objectives represent the first and second steps in the sequence of prevention of sports injuries.²⁰ Thereafter, injury prevention programs can be developed.

Materials and methods

Participants and Procedure

In collaboration with the FFME, an online questionnaire was specifically developed to report climbers' sociodemographics, sport-related characteristics, and FRI.

FFME officials sent a mail to all the members of the sport federation aged 16+ in March 2018 (n=57179). In addition, an announcement with a link to the web page of the questionnaire was put on the homepage of the federation website. A reminder to

participate was sent by mail in June 2018 and the web announcement was updated. Participants had from March to September 2018 to participate.

This mail included an online link to a web page including an information notice mentioning that the study was interested in accidents occurring in single-pitch climbing routes excluding bouldering, multi-pitch and traditional climbing routes, and that, thereafter, prevention initiatives would be launched. It was also mentioned that the study was anonymous. After reading, participants were invited to participate or decline.

Parents of 16- and 17-year-old climbers were able to transfer the questionnaire to their children members of the FFME (n=5875), in accordance with the equality and citizenship law no. 2017-86 of 27 January 2017, which stipulates that minors aged 16 or 17 can participate in associations' actions without formal parental authorization.

This data collection was approved by the institutional boards of the FFME and of the [Author Institution].

Instruments/Measures

A specific questionnaire was developed for this study. A face and content validation was performed by soliciting feedback on the content and structure of the questionnaire from a sample of 27 climbers (novice to expert; French climbing scale: 5c to 8a; IRCRA: 10 to 23) including one climbing coach and one lecturer in the field of sport climbing.²¹

Climbers participated in three focus groups of 11, 8 and 6 climbers, respectively. Two individual interviews were conducted with the climbing coach and the lecturer. All participants were asked to report whether they understood the questions clearly and the extent to which the questions were a good reflection of their climbing experience.

Following discussions, minor adjustments were made.

The participants reported their age, sex and area of residence (French administrative division). The age variable was divided into six equal-sized groups.

Participants were asked to report their context of participation (indoors, outdoors), their years of experience (YE), their hours of participation per month (HP), and level of onsight climbing. YE and HP were divided into six equal-sized groups. For the level of onsight climbing, they were asked to give their regular indoor onsight level and their regular outdoor onsight level using the French climbing scale according to five levels: [4+; 5c], [5c+; 6b], [6b+; 7a], [7a+; 7c], and [7c+; ...].²² On the IRCRA reporting scale, these ratings correspond to [1; 10], [11; 13], [14; 17], [18; 21], [22; ...].²² The correlation between regular indoor and regular outdoor level was strong ($r(3449)=0.84$, $p\text{-value} < 0.0001$). Thus, a proxy regular onsight level variable was computed that used the highest onsight level reported. 12 participants did not report either their regular indoor onsight level or their regular outdoor onsight level and were excluded from the multivariable analysis.

Fall-related injuries (FRI)

An FRI was defined as “an injury that led to a time-loss from climbing that lasted at least 24 hours and that was caused by a climbing fall”.

Past 12 months fall-related injury (12-FRI). Participants were invited to report whether they had had an FRI in the past 12 months. This time period was chosen because previous studies showed 100% accuracy in athlete reporting of at least one injury vs. no injury, and follows the latest consensus statement for the recording and reporting of self-reported epidemiological data on injury in sport.^{23,24} If so, they were invited to report the nature of injuries sustained and, for each injury, to report the FRI mechanisms.

12-FRI mechanisms. To explore the diversity of mechanisms that could lead to 12-FRI, injured climbers were invited to answer in writing the question: “Could you specify the mechanisms of your fall-related injury (causes and course of the fall)?”

From the written description of 12-FRI mechanisms, we recoded climbers’ descriptions into three different fall temporality dimensions. The first dimension (FR: Fall Reasons)

included the reasons that led to the fall (fatigue, broken hold, etc.). The second dimension (FB: Fall Behaviors) included the climber's or belayer's behaviors during the fall (rope in a wrong position, etc.). The third dimension (FE: Fall Ending) included the details concerning the fall end (on the ground, an obstacle, etc.).

Each 12-FRI description was read carefully and for each new mechanism described by the participant in a specific temporality dimension, a new variable category was created in this dimension. Example: "I had an ankle sprain following a hold that broke while I was rock climbing, before I had clipped the first bolt that was 5 or 6 meters high, so I fell on the ground after hitting a ledge on the wall."

For the dimension FR, this climber had the code "BREAKING A HOLD" for having broken a hold while climbing. For the variable FB, the climber had the code "HITTING LEDGE" because he collided with a ledge while falling. For the variable FE, the climber had the code HITTING THE GROUND for having fallen on the ground.

Mechanisms leading to injury were separated according to the role of the injured climber. Some respondents sustained an injury as belayer while arresting a fall while the others were climbing.

After a complete analysis of participants' 12-FRI description and recoding into the appropriate dimension, we proceeded with a second analysis to group the different elements into common themes. In a final table, mechanisms were ranked from the most frequent to the least frequent.

All recoded themes and their summary significance are available in Supplementary digital material 1.

Whole career fall-related injury (ALL-FRI). Participants were invited to report whether they had had an FRI in all their years of participation. No further information was asked for because of the high probability of recall bias.^{23,24}

Sample representativity

Of 57,179 mails, 22,574 were opened (open rate: 39.5%). Of 22,574 mails opened, 3,919 answered (response rate: 17.4%, Age=36.6±12.6).

We assessed whether non-respondents differ significantly from respondents by comparing the final sample age, sex and area of residence (French administrative division) distribution with the federation members.

The final sample comprised 2,540 males (65%) and 1,379 females (35%) which is similar to the federation members' sex distribution (61% and 39%). Distribution of answers by regions of France compared with members by area of residence was also similar (Supplementary digital material 2: Supplementary Table I). Finally, the age distribution in the study sample was similar to the age distribution of the FFME members aged 16+ but in the study sample there were 4.5% fewer young climbers (aged 16-24) compared with FFME members (Supplementary digital material 2: Supplementary Table II).

Data analysis

First, we described sample descriptions by age, sex, context of participation, YE, HP, and on sight level. For each variable category, we computed the prevalence of 12-FRI and ALL-FRI.

Secondly, we performed two adjusted binary logistic regression models to estimate 12-FRI and ALL-FRI risk factors. Models included age, sex, context of participation, YE, HP, and on sight level. The variance inflation factor (VIF) was computed for each model to account for multicollinearity. For each variable, VIF was below 2.5, attesting an absence of problematic multicollinearity.²⁵

Odds-ratios (OR) and their 95% confidence interval (95% CI) were presented. The significant threshold was set at 0.05.

Thirdly, all interaction effects were tested two-by-two. An interaction model adjusted for age between YE and onsight level was presented. Output from this model was presented (i) graphically through the predicted prevalence calculated from this model by YE and onsight level, and (ii) in a table where OR and 95% CI were presented.

Finally, 12-FRI mechanisms were presented.

Results

Table 1 shows sample characteristics and 12-FRI and ALL-FRI prevalence.

334 climbers (9%) reported a 12-FRI. 1148 (29%) climbers reported an ALL-FRI.

12-FRI nature and risk factors

The nature of 12-FRI was sprains (26.6%), skin burns/wounds (22.0%), contusions (22.0%), fractures (15.0%), bruises (12.7%), and dislocations (1.7%).

Concerning 12-FRI, no statistically significant effect of sex, context of climbing, or onsight level was observed. 12-FRI were more frequent among younger climbers, those with fewer YE and those with higher HP. For example, climbers with 0 to 3 YE were 1.7 times more likely (95% CI = 1.2-2.6) to have sustained a 12-FRI compared with those with 5 to 8 YE. ORs increased to 2.0 (95% CI = 1.4-5.9) and 3.6 (95% CI = 2.2-6.3) compared with those with 8 to 14 YE and 14 to 23 YE, respectively. In addition, participants climbing more than 38 hours per month were 1.9 times more likely (95% CI = 1.2-3.2) to have sustained a 12-FRI compared with those climbing less than 8 hours.

Additional analysis adjusted for age showed an interaction effect between YE and onsight level. Figure 1 shows predicted prevalence of 12-FRI computed from the logistic regression model adjusted for age by YE and onsight level. Among climbers with 0 to 8 years of experience, those with a higher onsight level had a higher predicted prevalence of 12-FRI. By contrast, above 8 years of experience, the predicted prevalence of 12-FRI did

not increase with onsight level. For example, 10% of climbers with 0 to 3 YE and an onsight level between 4+ and 5c reported a 12-FRI. 12% of those with an onsight level between 5c+ and 6b, and 17% of those with an onsight level higher than 6b+ did so. By contrast, for climbers with 8 to 14 YE, the prevalence of 12-FRI was similar regardless of their onsight level (4+ to 5c: 8%; 5c+ to 6b: 6%; 6b+ to 7a: 8%; more than 7a+: 9%).

Table 2 shows the OR and their 95% CI from this interaction model. It shows that the least experienced climbers with an onsight level between 6b+ and 7a were 1.9 times more likely (95% CI = 1.0-3.6) to have sustained a 12-FRI compared with those with an onsight level between 4+ and 5c. ORs increased to 2.4 (95% CI = 1.0-6.4) for the same comparison in the subgroup with 3 to 5 YE. Increasing OR were also observed with an increase in onsight level among the 5 to 8 years of experience subgroup, though not statistically significant. Finally, no increase in OR was observed among more experienced groups, and even a decrease was observed among the 14 to 23 YE subgroup.

12-FRI mechanisms

Table 3 shows the diversity of FRI mechanisms classified into the three temporalities: FR, FB, and FE. The meaning of each fall mechanism is provided in Supplementary digital material 1.

Among FR, apart from “natural” reasons for falling (physical and/or technical limitation), injured climbers reported 10 different FRI reasons. These reasons were classified into three main themes: unstable holds, pop-off and security errors. Injured belayers reported only two FRI reasons: broken hold and inability to give slack.

Among FB, injured climbers reported 12 different behaviors. Among these 12 behaviors, 4 were identified as a belayer behavior while they were falling: static belaying, letting go of the rope, not being careful, rope removed from the belay device. Injured belayers reported

three different behaviors: staying (or being) directly below the climber while he was falling, lifted from the ground, static belaying.

Finally, injured climbers reported 7 different FE. Six mechanisms were related to the structure they hit (for example, wall, ground, ledge). One mechanism was related to the body position at the end of the fall (head down position). Injured belayers reported three different FE: hitting the wall, hitting the belayer, or being struck by a rock fall.

ALL-FRI risk factors

Concerning ALL-FRI, as with 12-FRI, they were more likely among those with higher HP. In contrast to 12-FRI, they were more likely among older and more experienced climbers compared with younger and less experienced climbers. For example, climbers with 3 to 5 YE were 1.6 times more likely (95% CI = 1.2-2.1) to have sustained an ALL-FRI compared with those with 0 to 3 YE. ORs increased to 2.0 (95% CI = 1.5-2.6) and 2.1 (95% CI = 1.6-2.9) among those with 8 to 14 and 23 to 60 YE compared with those with 0 to 3 YE. In addition, ALL-FRI was more likely among those climbing outdoors compared with those climbing only indoors (OR_{outdoor only/indoor only}: 1.4 and 95% CI: 1.0-2.1, OR_{mixed/indoor only}: 1.2 and 95% CI: 1.0-1.6).

Discussion

The main purpose of this study was to measure the prevalence and risk factors of FRI in a representative sample of French climbers who were members of the FFME. The second objective was to explore FRI mechanisms.

From our sample, overall 9% of climbers have sustained a 12-FRI. This prevalence was higher than reported among Swedish Climbing Association members in 2005 (4%). The prevalence of ALL-FRI was significantly higher (29%).

Concerning 12-FRI risk factors, no sex effect was observed. Being a younger climber, with fewer YE and higher HP were risk factors for 12-FRI. Additional analyses adjusted for age showed that climbers with few YE and who already have an advanced onsight level had among the highest prevalence of 12-FRI. By contrast, climbers with more YE had a lower increase in OR with an increase in onsight level; and even for some subgroups, a decreased OR. These results add to the existing literature which has shown an increased injury risk among more experienced and more skilled climbers, without investigating specifically an interaction effect between the two.¹⁹

In our opinion, this result could be due to a greater acceptance of falling among climbers who have progressed rapidly in climbing. Falling in climbing is part of the process of achieving the hardest route possible. However, less experienced climbers do not yet have a large body of experience in climbing that can help to anticipate falls, to know how to fall and how to arrest a fall.^{6,7} This could result in more FRIs among these specific subgroups of climbers. A further study could be developed specifically to test this hypothesis, for example by measuring the association between speed of progress in climbing, fall probability, and FRI risk.

In a practical perspective, these results highlight the important effort that should be made in prevention among inexperienced climbers, and especially among those who progress rapidly in climbing. These results should raise awareness among physical education teachers and youth climbing coach regarding the FRI risk, as it has also already been shown that young climbers are at higher injury risk compared to other sports disciplines.²⁶ To help the development of future FRI prevention programs, this study also provided the list of FRI mechanisms that were reported by climbers. The analysis of fall reasons (FR),

fall behaviors (FB), and fall ending (FE) revealed interesting patterns that could help the development of such programs.

Concerning the FR, they can be grouped into three different categories.

The first category is *natural* falls, which occurred without any other reason than a physical or technical limitation of the climber. This type of fall can be considered the most natural in climbing, mostly harmless under the recommended positioning and belaying while falling.⁶

The second category of FR is unexpected falls. Hence, the second most reported reasons for FRI were unstable holds and pop-off. In sport climbing, a hold that breaks or turns, or a foot or hand pop-off, are unexpected events. These events can lead to the climber's fall even in the least difficult passages of the climb. In that case, for both the climber and the belayer, the fall is unexpected and can lead to a wrong position while falling or an inappropriate belaying technique to arrest the fall. This chain of events was observed in some written descriptions of FRI mechanisms. For example, one climber said: "I had a foot pop off in a slab climb. I hit the wall with my left foot while I was falling." For this climber, his fall resulted in an Achilles tendon injury. Another climber said: "In a local competition, I had clipped the two first and was starting to clip the third one. I had a foot pop off and I hit the ground," In both cases, specific training for climbers and belayers regarding unexpected falls could be developed in order to prevent FRI. These programs could teach belayers the need to stay focused in all circumstances while belaying (for example in passages of low difficulty), as previously mentioned.⁸

The last category of fall reasons was security errors such as a belayer who descends the climber too fast, resulting in the climber hitting an obstacle on the wall. Some FRI also happen due to a climber removing his anchor from the belay device without having

communicated with his belayer. These fall reasons are more “classic” security errors which should obviously be taught in climbing courses.

Concerning fall behaviors (FB), having been abruptly arrested (static belaying) was the most reported. Thus, for example, one climber reported: “I fell in lead climbing indoors on an overhanging route. My belayer did not dynamize my fall, I hit the wall hard.” This climber suffered a grade III ankle sprain. Another simply declared: “I had an ankle sprain after having hit the wall hard following a non-dynamic belaying.” All these scenarios could be limited by teaching climbers and belayers how to belay dynamically.

Concerning ALL-FRI risk factors, consistent with previous studies^{10,27} and in contrast to 12-FRI, those climbing outdoors were more likely to have sustained one than those climbing only in the indoor context (ALL-FRI prevalence: 34% vs. 20%). This may be due to the instability of rock handholds, and a greater vertical height between anchors, leading to longer falls. In addition, outdoor walls are more likely to present obstacles like ledges or trees that can be hit by the climber while falling.

Limitations

The main limitation of this study concerns the low response rate (17.4%). The sample obtained from the present study might suffer from selection bias, which implies a limited external validity of this study’s results. While participants’ sociodemographics were similar to those of FFME members in terms of sex and area of residence, the sample studied comprised 4.5% fewer climbers aged 16-24 compared with FFME members. This suggests that FRI prevalence observed in the present study might have been underestimated. Indeed, being young was found to be a risk factor for 12-FRI.

In addition, other selection biases might exist. In this study, participants were invited by mail by FFME officials. The information notice indicated that this study concerned injury

in climbing. One could argue that this type of study might attract specific subgroups of participants more interested in injury and accident risk reduction.²⁸ Consequently, as shown by a previous study which specifically analyzed the profile of non-responders to a questionnaire about respiratory symptoms and diseases, non-responders had greater risk exposure and health problems compared with responders.²⁹ Thus, the present study sample might represent to a greater extent climbers with relatively “safe” practice, which could have led to an underestimation of FRI prevalence compared with the whole population of FFME members. Further studies should obtain higher response rates to determine FRI prevalence with accuracy among FFME members.

Secondly, participants were invited to report 12-FRI and ALL-FRI. Previous studies conducted to test the accuracy of self-report injury showed that the greater the time since injury, the more imprecise is the recall. A study has shown that participants reported with 100% accuracy whether they had – or not – had an injury in the past 12 months.²³ However, if injury number, location, and nature were asked for, the accuracy decreased to 61.4%. In the present study, results concerning the nature of 12-FRI should therefore be considered with caution. Further studies should be developed with lower injury recall period and, ideally, assessed by medical staff to ensure more accurate classification.²⁴ Finally, in view of this information, ALL-FRI prevalence and risk factors should also be considered with caution.

Thirdly, for reasons mentioned in the Materials and methods section of the present study, the question regarding FRI mechanisms was exploratory. The objective was to catch the diversity of FRI mechanisms. It was thus impossible to quantify the respective contribution of each mechanism to understanding FRI. A further study should develop a specific quantitative measure of FRI mechanisms that could be tested in real-life

situations. For example, it would be interesting to use such a questionnaire in a large climbing gym over multiple years to determine FRI mechanisms with accuracy.

Conclusions

In this study of national members of FFME, FRI were more likely to be reported by younger and less experienced climbers. Among less experienced climbers, those with a high onsight level were more likely to have sustained a 12-FRI. By contrast, 12-FRI likelihood did not differ significantly as a function of the onsight level of the more experienced climbers. The results encourage development of FRI prevention programs focusing on the acquisition of specific skills that would target as a priority climbers with few years of experience, especially those who have progressed rapidly in climbing.

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Authors' contributions.— CM and PL developed the questionnaire and collected data among FFME members. CM was in charge of the ethical committee procedure. ML and CM wrote the introduction, methods, results, and discussion. ML did the statistical analysis. ML, PL and CM reviewed the introduction, methods, results and discussion. All authors read and approved the final version of the manuscript.

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TABLES

Table I.— *Sociodemographics, sport participation and fall-related injuries*

Table 1 Sociodemographics, sport participation and fall-related injuries

Variables		At least one 12-FRI		Adjusted coefficients for 12-FRI		At least one ALL-FRI		Adjusted coefficients for ALL-FRI	
	n	%	n	%	OR (95% CI)	n	%	OR (95% CI)	
Age									
[16 ; 24]	683	17%	88	13%	ref.	191	28%	ref.	
[24 ; 30]	680	17%	64	9%	0.7 (0.5-1.0)*	170	25%	0.8 (0.7-1.1)	
[30 ; 35]	642	16%	54	8%	0.7 (0.5-1.0)*	170	26%	0.9 (0.7-1.2)	
[35 ; 41]	679	17%	42	6%	0.5 (0.3-0.8)**	181	27%	0.9 (0.7-1.2)	
[41 ; 50]	652	17%	46	7%	0.6 (0.4-1.0)*	197	30%	1.0 (0.8-1.3)	
[50 ; 80]	583	15%	40	7%	0.7 (0.4-1.2)	239	41%	1.6 (1.2-2.1)**	
Sex									
Women	1379	35%	131	9%	ref.	374	27%	ref.	
Men	2540	65%	203	8%	0.9 (0.7-1.1)	774	30%	0.9 (0.8-1.1)	
Context of Climbing									
Indoor Only	671	17%	56	8%	ref.	137	20%	ref.	
Outdoor Only	200	5%	10	5%	0.8 (0.3-1.5)	68	34%	1.4* (1.0-2.1)	
Mixed	2975	76%	265	9%	1.2 (0.8-1.7)	924	31%	1.2* (1.0-1.6)	
NA	73	2%	3	4%		19	26%		
Years of Experience									
[0 ; 3]	928	24%	119	13%	ref.	156	17%	ref.	
[3 ; 5]	572	15%	57	10%	0.7 (0.5-1.0)	152	27%	1.6 (1.2-2.1)***	
[5 ; 8]	514	13%	46	9%	0.6 (0.4-0.9)**	166	32%	1.9 (1.5-2.5)***	
[8 ; 14]	644	16%	49	8%	0.5 (0.3-0.7)***	213	33%	2.0 (1.5-2.6)***	
[14 ; 23]	628	16%	24	4%	0.3 (0.2-0.5)***	206	33%	1.9 (1.4-2.5)***	
[23 ; 60]	633	16%	39	6%	0.5 (0.3-0.8)**	255	40%	2.1 (1.6-2.9)***	
Hours of Participation per Month									
[0 ; 8]	699	18%	44	6%	ref.	144	21%	ref.	
[8 ; 13]	634	16%	48	8%	1.2 (0.7-1.9)	162	26%	1.2 (0.9-1.6)	
[13 ; 19]	590	15%	47	8%	1.2 (0.8-1.9)	175	30%	1.4 (1.1-1.9)*	
[19 ; 26]	680	17%	50	7%	1.1 (0.7-1.8)	208	31%	1.4 (1.0-1.8)*	
[26 ; 38]	585	15%	59	10%	1.6 (1.0-2.6)	194	33%	1.5 (1.1-2.0)*	
[38 ; 140]	634	16%	76	12%	1.9 (1.2-3.2)**	235	37%	1.6 (1.2-2.1)**	
NA	97	2%	10	10%	NA	30	31%	NA	
Regular Onsite Level									
[4+ ; 5c]	700	18%	64	9%	ref.	145	21%	ref.	
[5c+ ; 6b]	1918	49%	152	8%	1.0 (0.7-1.3)	526	27%	1.2 (1.0-1.5)	
[6b+ ; 7a]	902	23%	86	10%	1.2 (0.8-1.8)	319	35%	1.6 (1.2-2.1)**	
[7a+ ; 7c]	341	9%	31	9%	1.1 (0.6-2.0)	142	42%	1.8 (1.3-2.6)**	
[7c+ ; ...]	46	1%	1	2%	0.2 (0.0-1.2)	14	30%	1.2 (0.6-2.5)	
NA	12	0%		0%	NA	0	NA	NA	
Total	3919	100%	334	9%		1148	29%		

Note. 12-FRI: Fall-related injury in the past 12 months; ALL-FRI: Fall-related injury over the entire career. **Bold** value indicates a statistically significant effect. *p-value<0.05, **p-value<0.01, ***p-value<0.001. No statistically significant interaction effect (p<0.05) was observed between Age and Sex, Age and Context, Age and Years of Experience, Age and Hours of Participation per Month, Age and Regular Onsite Level, Sex and Context, Sex and Years of Experience, Sex and Hours of Participation per Month, Sex and Regular Onsite Level, Context and Years of Experience, Context and Hours of Participation per Month, Context and Regular Onsite Level, Years of Experience and Hours of Participation per Month, Hours of Participation per Month and Regular Onsite Level.

Table II.— *Age-adjusted regression analysis between years of experience * onsite level and past 12 months fall-related injury*

Table 2. Age-adjusted regression analysis between years of experience * onsite level and past 12 months fall-related injury

Variables	0 to 3 years OR (95% CI)	3 to 5 years OR (95% CI)	5 to 8 years OR (95% CI)	8 to 14 years OR (95% CI)	14 to 23 years OR (95% CI)	23 to 60 years OR (95% CI)
4+ ; 5c				<i>ref.</i>		
5c+ ; 6b	1.2 (0.8-1.9)	1.3 (0.6-3.2)	1.7 (0.5-7.2)	0.7 (0.3-2.1)	0.2 (0.0-0.8)*	0.5 (0.2-1.7)
6b+ ; 7a	1.9 (1.0-3.6)*	2.4 (1.0-6.4)*	2.5 (0.8-11.0)	1.2 (0.5-3.3)	0.5 (0.1-1.9)	0.5 (0.2-1.8)
7a+ ; 7c	NA	1.8 (0.4-7.2)	3.4 (0.8-17.1)	1.4 (0.5-4.4)	1.0 (0.3-4.1)	0.6 (0.2-2.2)
7c+ and higher	NA	NA	NA	0.0 (0.0-3.5*10 ⁷)	0.7 (0.0-4.9)	0.0 (0.0-2.6*10 ¹²)

Note. OR: Odds-ratio. 95% CI: 95% Confidence interval. NA: insufficient sample size to compute estimates. **Bold** values indicate a statistically significant effect at the 0.05 level.

Table III.— *Role of injured climbers and declared fall reasons, behaviors and ending that led to past 12 months fall-related injury*

Table 3. Role of injured climbers and declared fall reasons, behaviors and ending that led to past 12 months fall-related injury

Fall Reasons		Fall Behaviors		Fall Ending	
Role	Themes	Role	Themes	Role	Themes
CLIMBER INJURED		CLIMBER INJURED		CLIMBER INJURED	
	<i>NO SPECIFIC REASON (e.g., physical and/or technical limitation)</i>		<i>STATIC BELAYING</i>		<i>HITTING</i>
	<i>UNSTABLE HOLDS</i>		<i>HITTING LEDGE</i>		<i>WALL</i>
	<i>BREAKING A HOLD</i>		<i>ROPE WRONG POSITION</i>		<i>GROUND</i>
	<i>TURNING HOLD</i>		<i>WRONG POSITION OF THE BODY</i>		<i>LEDGE</i>
	<i>POP-OFF</i>		<i>BELAYER LETTING GO OF THE ROPE</i>		<i>HOLD</i>
	<i>FOOT</i>		<i>BELAYER NOT CAREFUL</i>		<i>TREE</i>
	<i>HAND</i>		<i>JAM</i>		<i>BELAYER</i>
	<i>SECURITY ERRORS</i>		<i>FOOT JAM</i>		<i>HEAD DOWN POSITION</i>
	<i>DESCENT TOO FAST</i>		<i>KNEE JAM</i>	BELAYER INJURED	
	<i>TOOK OFF ANCHOR WITHOUT NOTICE</i>		<i>FINGER JAM</i>		<i>HITTING</i>
	<i>DYNAMIC MOVEMENT AT THE START</i>		<i>GRASPING SOMETHING</i>		<i>WALL</i>
	<i>ABSEIL WITHOUT DESCENDER</i>		<i>HOLD</i>		<i>CLIMBER</i>
	<i>ROPE TOO SHORT</i>		<i>CARABINER</i>		<i>STRUCK BY A ROCK FALL</i>
	<i>HONEYCOMB</i>		<i>ROPE REMOVED FROM THE BELAY DEVICE</i>		
BELAYER INJURED		BELAYER INJURED			
	<i>BROKEN HOLD</i>		<i>DIRECTLY BELOW CLIMBER</i>		
	<i>INABILITY TO GIVE SLACK</i>		<i>LIFTED FROM THE GROUND</i>		
			<i>STATIC BELAYING</i>		

Note. Each mechanisms description is available in supplementary digital material 1.

FIGURES



Figure 1.— Predicted prevalence of 12-FRI by YE and onsite level, adjusted for age

Note. 12-FRI: Past 12 months fall-related injury; YE: years of experiences. Reading: 17% of climbers with 0 to 3 years of experience and an onsite level between 6b+ and 7a had a 12-FRI, adjusted for age