Comparative grading scales, statistical analyses, climber descriptors and ability grouping: International Rock Climbing Research Association Position Statement

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Abstract

The research base for rock climbing has expanded substantially in the past 3 decades as worldwide interest in the sport has grown. An important trigger for the increasing research attention has been the transition of the sport to a competitive as well as recreational activity and the potential inclusion of sport climbing in the Olympic schedule. The International Rock Climbing Research Association (IRCRA) was formed in 2011 to bring together climbers, coaches and researchers to share knowledge and promote collaboration. This position statement was developed during and after the 2nd IRCRA Congress which was held in Pontresina, in September 2014. The aim of the position statement is to bring greater uniformity to the descriptive and statistical methods used in reporting rock climbing research findings. To date there is a wide variation in the information provided by researchers regarding the climbers' characteristics and also in the approaches employed to convert from climbing grading scales to a numeric scale suitable for statistical analysis. Our paper presents details of recommended standards of reporting that should be used for reporting climber characteristics and provides a universal scale for the conversion of climbing grades to a number system for statistical analysis.

Keywords: Rock climbing, ability grouping, climbing grade, comparative table, statistics

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Introduction

The International Rock Climbing Research Association (IRCRA) was formed in 2011 as a forum through which climbers, coaches and researchers, working in the area of rock climbing, could come together to share experience, collaborate over research and to provide a platform for knowledge exchange. To date the Association has held two Congresses, the first in 2011 in Christchurch, New Zealand, and the second in Pontresina, Switzerland in 2014. The next Congress will be held in the USA in 2016. Membership of the Association is free and includes climbers, coaches, climbing wall designers and researchers from around the world; the website for the IRCRA can be found at www.ircra.rocks.

Rock climbing is an increasingly popular recreational and competitive sport, with a growing research base (Watts, 2004; España Romero, 2009; Draper et al., 2011a; Baláš et al., 2014). As the sport has developed the number of disciplines has increased and now includes such diverse activities as mountaineering, big wall climbing, bouldering, deep water soloing, sport climbing, traditional climbing, ice climbing and mixed climbing (MacLeod et al., 2007). As the research base has grown, ~550 papers have been published on the sport, there has been an increasing diversity in the nomenclature to describe ability groups, the grading systems and climber characteristics reported as well as a wide variety of grade conversion methods employed to enable statistical analysis of results (Schoeffl et al., 2004; MacLeod et al., 2007; España Romero et al., 2009; Sherk et al., 2010). In 2011, Draper et al. (2011b) published a paper highlighting such discrepancies and the resultant problems consequently arising for researchers attempting to make comparisons between studies. However, since that paper was published, the non-consistency in reporting has continued (Amca et al., 2012; Morenas Martín et al., 2013; Laffaye et al., 2014; Woollings et al., 2014; Young et al., 2014). The climbers, coaches and researchers present at the 2014 International Rock Climbing Research Congress developed this position statement as a call to all involved in climbing research to follow a consistent method for reporting climber characteristics, nomenclature for ability grouping and to propose the use of one IRCRA scale in all statistical analyses. Such an approach will improve consistency in the field and facilitate comparison between studies.

Climbing scales and recommendations for statistical analysis

As can be seen from Table 1, there are a variety of climbing scales used around the world and also for different disciplines. The Yosemite Decimal System (YDS) is used in the USA. The French/sport scale is used for sport climbing in Europe. The British technical grading scale, usually used in conjunction with an adjectival scale, is used to express the difficulty of traditional routes, where equipment is placed into the rock en-route to protect the lead climber against a fall during ascent. The Ewbank scale is primarily used in Australia, New

Zealand and South Africa, while the Union Internationale des Associations d'Alpinisme scale (UIAA) is primarily used to describe difficulty of short rock routes in Germany, Austria, Switzerland, Czech Republic, Slovakia and Hungary. The Vermin (V) and Font (Fontainebleau) scales are used to describe the difficulty of a bouldering climbing problem.

Table 1. Ability grouping for males and females and a range of reporting scales shown alongside the IRCRA scale.

Climbing Group		Vermin	Font	**IRCRA Reporting Scale**	YDS	French/sport	British Tech	Ewbank	BRZ	UIAA	Metric UIAA	Watts
Lower Grade (Level 1) Male & Female				**1**	5.1	1	2	4	I sup	I	1.00	
				2	5.2	2		6	II	II	2.00	
				3	5.3	2+	3	8	II sup	III	3.00	
				4	5.4	3-			III	III+	3.50	
				5	5.5	3		10	IV	IV	4.00	
				6	5.6	3+	4	12	V	IV+	4.33	0.00
				7	5.7	4		14		V-	4.66	0.25
				8	5.8	4+			V	V	5.00	0.50
		VB	< 2	**9**	5.9	5	5a	16	V sup	V+	5.33	0.75
				10	5.10a	5+		18	VI	VI-	5.66	1.00
	Intermediate (Level 2) Female	V0-	3	**11**	5.10b	6a	5b	19		VI	6.00	1.25
		V0	4	**12**	5.10c	6a+			VI sup	VI+	6.33	1.50
Intermediate (Level 2) Male		V0+	4+	**13**	5.10d	6b	5c	20		VII-	6.66	1.75
		V1	5	**14**	5.11a	6b+		21	7a	VII	7.00	2.00
			5+	**15**	5.11b	6c	6a	22	7b	VII+	7.33	2.25
		V2	6A	**16**	5.11c	6c+				VIII-	7.66	2.50
	Advanced (Level 3) Female	V3	6A+ 6B	**17**	5.11d	7a		23	7c	VIII	8.00	2.75
		V4	6B+	**18**	5.12a	7a+	6b	24	8a	VIII+	8.33	3.00
		V5	6C	**19**	5.12b	7b		25	8b	IX-	8.66	3.25
Advanced (Level 3) Male		V6	6C+ 7A	**20**	5.12c	7b+		26	8c			3.50
		V7	7A+	**21**	5.12d	7c	6c	27	9a	IX	9.00	3.75
		V8	7B	**22**	5.13a	7c+		28	9b	IX+	9.33	4.00
	Elite (Level 4) Female	V9	7B+	**23**	5.13b	8a		29	9c	X-	9.66	4.25
			7C	**24**	5.13c	8a+		30	10a	X	10.00	4.50
Elite (Level 4) Male		V10	7C+	**25**	5.13d	8b	7a	31	10b			4.75
		V11	8A	**26**	5.14a	8b+		32	10c	X+	10.33	5.00
		V12	8A+	**27**	5.14b	8c	7b	33	11a	XI-	10.66	5.25
		V13	8B	**28**	5.14c	8c+		34	11b	XI	11.00	5.50
	Higher Elite (Level 5) Female			**29**	5.14d	9a		35	11c			5.75
Higher Elite (Level 5) Male		V14	8B+	**30**	5.15a	9a+		36	12a	XI+	11.33	6.00
		V15	8C	**31**	5.15b	9b		37	12b	XII-	11.66	6.25
		V16	8C+	**32**	5.15c	9b+		38	12c	XII	12.00	6.50

Note. IRCRA stands for the International Rock Climbing Association; YDS for Yosemite Decimal System; BRZ for Brazilian scale, UIAA for the Union Internationale des Associations d'Alpinisme and Font for Fontainebleau. Sources: Watts, Martin & Durtschi (1993), Benge & Raleigh (1995), Draper et al. (2011b), Schöffl et al. (2010), BMC (2007), Rockfax (n.d.), The American Alpine Club (2012).

As can be seen from Table 1, the climbing scales are subdivided by letters or +/- grades or are incomplete scales and as such make direct statistical analysis impossible. To overcome this difficulty, researchers have developed number-based scales, converting to them for statistical analyses (Padrenosso et al. 2008; Llewellyn & Sanchez, 2008; Michailov et al. 2009; Draper et al., 2009; Schöffl et al., 2010). The problem with this approach is that, again, there has been little consistency between methods. The first to develop such a scale were Watts, Martin & Durtschi (1993) and this is presented in the Table for reference, however as an incomplete scale (the scale starts at 5.6 YDS rather than 5.1) it could not be used as a statistical scale for all rock climbing studies. The Ewbank and UIAA Decimal scale also had potential, however, both are incomplete scales, the Ewbank additionally starting at level 4. The Sport and YDS scales, the most widely used scales, have 32 grades and as such the Ewbank and UIAA decimal, having only 28 grades, would make conversion to either of these scales problematic. As a consequence the IRCRA scale, also shown in Table 1 and Figure 1, is proposed as the recommended scale to use for statistical analyses in future studies, as one that matches the number of grade steps in the most commonly used climbing scales. As can be seen from Figure 1, all existing scales, at least at higher difficulty levels, show a linear relationship with the IRCRA scale.

Insert Figure 1 near here

Ability grouping

In the climbing grades paper written by Draper and co-workers (2011b), the authors highlighted inconsistencies in language and ability grouping criteria used to describe climbers and the problems this causes when attempting to make comparisons between studies (Grant et al., 1996; Grant el al., 2001; Boschker et al., 2002; Limonta et al., 2008; Esposito et al., 2009). Draper et al. (2011b) proposed the nomenclature for climbing ability as shown in Table 1, establishing five groups from low grade to higher elite level climbers. Despite the publication of the paper by Draper et al. (2011b) studies continue to be published with inconsistencies in the language used to describe the groups in their studies. By way of recent examples, Laffaye et al. (2014) categorised their climbers as novice (<6a), skilled (6c–7b) or elite (≥8a) while Lechner et al. (2013) classified climbers as experienced or less experienced without stating the grounds upon which the categorisation was made. In 2014 Young et al. again used the experienced or inexperienced categorisation, however, in this study they classified each as having ascended more than 50 vertical climbs or fewer than 5 vertical ascents respectively. While not of relevance to their study this categorisation would leave a middle group of climbers who ascended between 5 – 49 climbs in an unnamed group and would not differentiate between climbers who have climbed 50 routes and those with thousands. While this would not matter for the particular study reported by Young and colleagues (2014), it does not help readers to draw conclusions of findings between studies.

In a paper published in Wilderness and Environmental Medicine, Folkl stated (2013, p.155):

> *"At the time of study design there was no known consensus regarding an appropriate approach to stratifying survey respondents based on level of difficulty climbed. Therefore, for the purposes of this report respondents were asked to categorize themselves as, on average, able to climb 5.0-5.9, 5.10a-5.10d, 5.11a-5.11d, 5.12a-5.12d, 5.13a-5.13d, or 5.14a and above."*

This statement, not only identifies a further novel approach to classifying climbers, it also highlights the case for reaching consensus detailed in this IRCRA position statement. The consensus reached in this paper will enable future researchers to refer to an agreed system of categorising climber abilities and to employ a common language as descriptors for specific ability groups.

Draper et al. (2011b) created two tables of climber abilities, one for males and one for females. During the process of reaching the consensus for this position statement members of the IRCRA discussed the merits of having separate classifications of ability for male and female climbers. While there were a number of researchers and climbers who supported the notion of one table for all, the consensus suggested we should take note from previous research outside the field which sees separate fitness results tables and performance records (such athletics world records) for males and females. Rather than creating two tables as was the case for Draper et al. (2011b), for ease of comparison, Table 1 presents the groups and breakpoints between group for males and females in one table.

Climber characteristics: Capturing the group

A further key aspect in reporting both climber abilities and the characteristics of climbers relates to which aspects should be reported. Again we see wide discrepancies between studies and this can be very problematic for making comparison between studies (Schoeffl et al., 2004; Fryer et al., 2012; Baláš, et al., 2012; Donath et al., 2013; Fanchini et al., 2013; Green, Draper & Helton, 2013; Schöffl et al., 2013). In addition to the normal data collected such as age, gender, body mass and height, to better inform readers of future research papers and to facilitate comparison between studies a number of regular characteristics should be reported by authors. It should be noted that the classification of climbers in Table 1 relates to their highest self-reported redpoint ascent. A redpoint, from the German rotpunkt, referring to a successful lead climb ascent, without weighting the rope, of a route previously practised route. Previous research by Draper et al. (2011a) indicates that the use of self-report grades is appropriate as climbers have been shown to accurately self-report their climbing ability in a research context.

A number of IRCRA members highlighted the need for clarity regarding what would constitute a highest redpoint grade, for instance as Fanchini (2014) stated, would making a successful ascent of one route which suited a particular climber's characteristics (anthropometry etc.) constitute a fair and accurate assessment of their ability. Drum (2014)

proposed an excellent solution for reporting; the 3:3:3 rule. When completing the climbing ability assessment researchers should record the climber's highest redpoint grade for which they have completed 3 successful ascents on 3 different routes (at the grade) within the previous 3 months. For ease of comparison, this should be reported as local grade as well as sport/French, YDS and IRCRA. By way of example, as can be seen from Table 1, a study in South Africa might report findings for a group of advanced level female climbers with a mean self-reported ability of 23 Ewbank (7a sport/French, 5.11d YDS, IRCRA 17). While for an equivalent group of boulderers (female advanced level), the mean climbing grade might be V6 (Font 7a, IRCRA 20). In addition, as a minimum, researchers should report answers to the following questions about the following characteristics of the climbers in a study to improve comparability between studies:

- Climbers' self-identity in the sport – how they see themselves in-terms of predominant discipline (i.e. boulderer, sport climber, etc.)?
- Disciplines (i.e. bouldering, sport, traditional etc.) the climbers take part in (percentage of time devoted to each) in the past 3 and 12 months (include data for both time periods)?
- Percentage of time spent climbing indoors or outdoors in the past 3 months and over the past 12 months?
- Mean time (days per week and hours per session) spent climbing/training in a typical week in past 3 months and in the past 12 months?
- Time in the sport – the number of years/months experience?
- Are they involved in competition climbing, along with the disciplines and levels (i.e. bouldering, local versus national competitions)?
- Additionally researchers might report the climbers' preference for style of ascent, (i.e. onsight, redpoint, top-rope) and for terrain (vertical, overhanging, slab climbing, varied).

Future research

Table 1 provides a conversion between climbing grade scales used in different countries or regions of the world. Those involved with climbing know that although these appear objective when viewed in a table such as this, the grading of a particular route is inherently more subjective in nature. Although perhaps made more objective over time through repeat ascents and confirmation (or often down-grading) of the original grade, there remains an element of subjectivity to grade assignment for any particular route. Conversion between scales, such as from YDS to Ewbank, should therefore be completed with some caution. Likewise, while the IRCRA scale might appear to represent a ratio scale and was developed in an objective manner, conclusions drawn in regard to the ability of climbers should, at this stage, also be made with some reservation. Furthermore, scales such as the British adjectival scale, appear to have psychological barriers which have arisen, often through climbing

folklore, around specific grades. These may well affect the rate at which climbers move through grades or appear to have sticking points in their progression due to such barriers. Examples of this might include the E1, the first ‘extreme’ grade climb in traditional climbing, the 21 grade in Australia using the Ewbank scale or the 5.13 YDS grade.

This raises two issues in this aspect of climbing research that perhaps merit further attention. Firstly, research into the presence of certain psychological ‘sticking points’ could usefully be undertaken in the near future. It may be likely that the steps between grades are not of a ratio scale nature, but more likely ordinal and should perhaps therefore be treated as such, which has implications for further statistical analyses. Secondly, it would seem beneficial, in attempting to quantify the ability of climbers to (a) agree on a battery of valid and reliable measures of climbing ability and then to (b), using a large sample of climbers across a range of abilities, assess performance on this battery of tests to create a more objective measure of climbing ability for use in future studies. Members of the IRCRA are in the process (April 2015 – April 2016) of completing a multi-centre collaborative research project to accomplish such a large-scale study. Researchers interested in being involved in this study should contact the corresponding author of this paper for details.

Conclusion

The increasing research attention on the sport of rock climbing highlights very clearly the continued discrepancies in reporting methods and approaches to statistical analysis evident between studies. The IRCRA scale, shown in Table 1, has been developed to support a common approach to statistical analyses. In addition, the ability grouping nomenclature also detailed in Table 1, along with the recommendations for reporting climber characteristics, if applied in reporting future studies will substantially increase the uniformity between papers and improve ease of comparison for readers. It is suggested that all future researchers follow the recommendations presented in this position statement and refer to Table 1 for statistical analysis and classification of the climbers in their studies.

References

Amca, A. M., Vigouroux, L., Aritan, S., & Berton, E. (2012). Effect of hold depth and grip technique on maximal finger forces in rock climbing. *Journal of Sports Sciences*, *30*(7), 669-77. doi:10.1080/02640414.2012.658845

Baláš, J., Panáčková, M., Strejcová, B., Martin, A. J., Cochrane, D. J., Kaláb, M., & Draper, N. (2014). The relationship between climbing ability and physiological responses to rock climbing. *Scientific World Journal*, *2014*(678387), 1-6. doi:10.1155/2014/678387

Baláš, J., Pecha, O., Martin, A. J., & Cochrane, D. (2012). Hand–arm strength and endurance as predictors of climbing performance. *European Journal of Sport Science*, *12*(1), 16-25. doi:10.1080/17461391.2010.546431

Benge & Raleigh (1995). *Rock: Tools and Technique.* Elk Mountain Press: USA.

BMC (2007). *A brief explanation of UK traditional climbing grades.* [online]. [Accessed 15 November 2014]. Available from: https://www.thebmc.co.uk/Download.aspx?id=108

Boschker, M. S., Bakker, F. C., & Michaels, C. F. (2002). Memory for the functional characteristics of climbing walls: Perceiving affordances. *Journal of Motor Behavior*, *34*(1), 25-36.

Donath, L., Roesner, K., Schöffl, V., & Gabriel, H. H. (2013). Work-relief ratios and imbalances of load application in sport climbing: Another link to overuse-induced injuries? *Scandinavian Journal of Medicine & Science in Sports*, *23*(4), 406-14. doi:10.1111/j.1600-0838.2011.01399.x

Draper, N., Brent, S., Hodgson, C., & Blackwell, G. (2009). Flexibility assessment and the role of flexibility as a determinant of performance in rock climbing. *International Journal of Performance Analysis in Sport*, *9*(1), 67-89.

Draper, N., Canalejo, J. C., Fryer, S., Dickson, T., Winter, D., Ellis, G., & North, C. (2011). Reporting climbing grades and grouping categories for rock climbing. *Isokinetics and Exercise Science*, *19*(4), 273-280.

Draper, N., Dickson, T., Blackwell, G., Fryer, S., Priestley, S., Winter, D., & Ellis, G. (2011a). Self-reported ability assessment in rock climbing. *Journal of Sports Sciences*, *29*(8), 851-8. doi:10.1080/02640414.2011.565362

Drum, S. (2014). Personal communication, 25/11/14.

Espana Romero, V., Ruiz, J. R., Ortega, F. B., Artero, E. G., Vicente-Rodriguez, G., Moreno, L. A., Castillo M. J., & Gutierrez, A. (2009). Body fat measurement in elite sport climbers: Comparison of skinfold thickness equations with dual energy x-ray absorptiometry. *Journal of Sports Sciences*, *27*(5), 469-77. doi:10.1080/02640410802603863

Esposito, F., Limonta, E., Cè, E., Gobbo, M., Veicsteinas, A., & Orizio, C. (2009). Electrical and mechanical response of finger flexor muscles during voluntary isometric contractions in elite rock-climbers. *European Journal of Applied Physiology, 105*(1), 81-92.

Fanchini, M. (2014). Personal communication, 23/09/14.

Fanchini, M., Violette, F., Impellizzeri, F. M., & Maffiuletti, N. A. (2013). Differences in climbing-specific strength between boulder and lead rock climbers. *The Journal of Strength & Conditioning Research, 27*(2), 310-314.

Folkl, A. K. (2013). Characterizing the consequences of chronic climbing-related injury in sport climbers and boulderers. *Wilderness & Environmental Medicine.*

Fryer, S., Dickson, T., Draper, N., Blackwell, G., & Hillier, S. (2012). A psychophysiological comparison of on-sight lead and top rope ascents in advanced rock climbers. *Scandinavian Journal of Medicine & Science in Sports*, *23*(5), 645-650. doi:10.1111/j.1600-0838.2011.01432.x

Grant, S., Hasler, T., Davies, C., Aitchison, T. C., Wilson, J., & Whittaker, A. (2001). A comparison of the anthropometric, strength, endurance and flexibility characteristics of female elite and recreational climbers and non-climbers. *Journal of Sports Sciences*, *19*(7), 499-505.

Grant, S., Hynes, V., Whittaker, A., & Aitchison, T. (1996). Anthropometric, strength, endurance and flexibility characteristics of elite and recreational climbers. *Journal of Sports Sciences, 14*(4), 301-309.

Green, A. L., Draper, N., & Helton, W. S. (2013). The impact of fear words in a secondary task on complex motor performance: A dual-task climbing study. *Psychological Research,* doi:10.1007/s00426-013-0506-8

Laffaye, G., Collin, J. -M., Levernier, G., & Padulo, J. (2014). Upper-limb power test in rock-climbing. *International Journal of Sports Medicine.* 35(8), 670-5. doi: 10.1055/s-0033-1358473

Lechner, B., Filzwieser, I., Lieschnegg, M., & Sammer, P. (2013). A climbing hold with an integrated three dimensional force measurement and wireless data acquisition. *International Journal on Smart Sensing and Intelligent Systems*, *6*(5), 2296-2307.

Limonta, E., Cè, E., Veicsteinas, A., & Esposito, F. (2009). Force control during fatiguing contractions in elite rock climbers. *Sport Sciences for Health, 4*(3), 37-42. doi:10.1007/s11332-008-0065-3

Llewellyn, D. J., & Sanchez, X. (2008). Individual differences and risk taking in rock climbing. *Psychology of Sport and Exercise*, *9*(4), 413-426. doi:10.1016/S0001-4575(99)00026-3

Macleod, D., Sutherland, D. L., Buntin, L., Whitaker, A., Aitchison, T., Watt, I., & Grant, S. (2007). Physiological determinants of climbing-specific finger endurance and sport rock climbing performance. *Journal of Sports Sciences*, *25*(12), 1433–1443. doi:10.1080/02640410600944550

Michailov, M. L., Mladenov, L. V., & Schöffl, V. R. (2009). Anthropometric and strength characteristics of world-class boulderers. *Medicina Sportiva*, *13*(4), 231-238. doi:10.2478/v10036-009-0036-z

Morenas Martín, J., Del Campo, V. L., Leyton Román, M., Gómez-Valadés Horrillo, J. M., & Gómez Navarrete, J. S. (2013). Description of the finger mechanical load of climbers of different levels during different hand grips in sport climbing. *Journal of Sports Sciences, 31*(15), 1713-21. doi:10.1080/02640414.2013.797592

Padrenosso, A., de Godoy, E. S., César, E., Barreto, A., Reis, V., Silva, A., & Dantas, E. (2008). Somatic and functional profile of sport rock climbers. *Physical Education and Sport, 52*(1), 73-76.

Rockfax (n.d.). Grade conversions. [online]. [Accessed 15 November 2014]. Available from: http://www.rockfax.com/publications/grades/

Schoeffl, V., Klee, S., & Strecker, W. (2004). Evaluation of physiological standard pressures of the forearm flexor muscles during sport specific ergometry in sport climbers. *British Journal of Sports Medicine*, *38*(4), 422-425. doi:10.1136/bjsm.2002.003996

Schöffl, V. R., Hoffmann, G., & Küpper, T. (2013). Acute injury risk and severity in indoor climbing-a prospective analysis of 515,337 indoor climbing wall visits in 5 years. *Wilderness & Environmental Medicine*, doi:10.1016/j.wem.2013.03.020

Schöffl, V., Morrison, A., Hefti, U., Ullrich, S., & Küpper, T. (2010). The UIAA medical commission injury classification for mountaineering and climbing sports. *Wilderness & Environmental Medicine*, *22*(1), 46-51.

Sherk, V. D., Sherk, K. A., Kim, S., Young, K. C., & Bemben, D. A. (2011). Hormone responses to a continuous bout of rock climbing in men. *European Journal of Applied Physiology*, *111*(4), 687-93. doi:10.1007/s00421-010-1685-2

The American Alpine Club (2012). *The American Alpine Journal.* The American Alpine Club: Canada.

Watts, P. B. (2004). Physiology of difficult rock climbing. *European Journal of Applied Physiology*, *91*(4), 361-72. doi:10.1007/s00421-003-1036-7

Watts, P. B., Martin, D. T., & Durtschi, S. (1993). Anthropometric profiles of elite male and female competitive sport rock climbers. *Journal of Sports Sciences*, *11*(2), 113-117.

Woollings, K. Y., McKay, C. D., Kang, J., Meeuwisse, W. H., & Emery, C. A. (2014). Incidence, mechanism and risk factors for injury in youth rock climbers. *British Journal of Sports Medicine.* doi:10.1136/bjsports-2014-094067

Young, P. R., Eklund, R. C., Tenenbaum, G., Glueckauf, R. L., & Thompson, B. (2014). Not so risky business: The use of planning within rock climbing. *Leisure*, *1*. doi:10.1080/14927713.2014.932970

Figure Legends

Figure 1: IRCRA Reporting Scale against existing difficulty scales; IRCRA stands for the International Rock Climbing Association; YDS for Yosemite Decimal System; BRZ for Brazilian scale, UIAA for the Union Internationale des Associations d'Alpinisme and Font for Fontainebleau.