RAPID COMMUNICATION

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 three 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 (IR CRA) 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...
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 (Baláš et al., 2014; Draper et al., 2011a; España Romero et al., 2009; Watts, 2004). 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 (España Romero et al., 2009; Macleod et al., 2007; Schoeffl, Klee, & Strecker, 2004; Sherk, Sherk, Kim, Young, & Bemben, 2011). 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 inconsistency in reporting has continued (Amca, Vigouroux, Aritan, & Berton, 2012; Laffaye, Collin, Levernir, & Padulo, 2014; Morenas Martin, Del Campo, Leyton Roman, Gomez-Valades Horcillo, & Gomez Navarrete, 2013; Woolings, McKay, Kang, Meeuwsse, & Emery, 2014; Young, Eklund, Tenenbaum, Glueckauf, & Thompson, 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 I, 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.

As can be seen from Table I, the climbing scales are subdivided by letters or +/− grades or are incomplete scales and as such make direct statistical analysis challenging. To overcome this difficulty, researchers have developed number-based scales, converting traditional climbing scales to number-based scales for statistical analyses (Draper, Brent, Hodgson, & Blackwell, 2009; Llewellyn & Sanchez, 2008; Michailov, Mladenov, & Schöffl, 2009; Padrenosso et al., 2008; Schöffl, Morrison, Hefti, Ullrich, & Küpper, 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, and 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 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
these scales problematic. As a consequence the IRCRA scale, also shown in Table I 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.

**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 these cause when attempting to make comparisons between studies (Boschker, Bakker, & Michaels, 2002; Esposito et al., 2009; Grant, Hynes, Whittaker, & Aitchison, 1996; Grant et al., 2001; Limonta, Če, Veicsteinas, & Esposito, 2009). Draper et al. (2011b) proposed the nomenclature for climbing ability as shown in Table I, 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, Filzwieser, Lieschnegg, and Sammer (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

| Climbing Group | IR CRA | Reporting Scale | YDS | French/sport | British Tech | Ewbank | BRZ | UIAA | Metric |
|----------------|--------|-----------------|-----|--------------|--------------|--------|-----|------|--------|
| Lower Grade (Level 1) Male & Female | 1      | 5.1             | 1   | II           | 1.00         |        |     |      |        |
|                | 2      | 5.2             | 2   | II           | 2.00         |        |     |      |        |
|                | 3      | 5.3             | 2+  | III          | 3.00         |        |     |      |        |
|                | 4      | 5.4             | 3   | III+         | 3.50         |        |     |      |        |
|                | 5      | 5.5             | 3+  | IV           | 4.00         |        |     |      |        |
|                | 6      | 5.6             | 4   | IV+          | 4.33         |        |     |      |        |
|                | 7      | 5.7             | 5   | V            | 4.66         |        |     |      | 0.25   |
|                | 8      | 5.8             | 5+  | V+           | 5.00         |        |     |      | 0.50   |
| V8 < 2        | 9      | 5.9             | 5a  | VI           | 5.66         |        |     |      | 0.75   |
|                | 10     | 5.10            | 6   | VI           | 6.00         |        |     |      |        |
| Intermediate (Level 2) Female | 11     | 5.10            | 6a  | VII          | 6.66         |        |     |      | 1.50   |
|                | 12     | 5.10            | 6a+ | VII+         | 6.66         |        |     |      |        |
| Intermediate (Level 2) Male | 13     | 5.10            | 6b  | VII          | 7.00         |        |     |      | 1.75   |
|                | 14     | 5.11            | 6b+ | VII          | 7.73         |        |     |      | 2.00   |
| Advanced (Level 3) Female | 15     | 5.11            | 6c  | VII          | 7.73         |        |     |      | 2.25   |
|                | 16     | 5.11            | 6c+ | VII          | 7.66         |        |     |      | 2.50   |
| Advanced (Level 3) Male | 17     | 5.11            | 7   | VII          | 8.00         |        |     |      | 2.75   |
|                | 18     | 5.12            | 7a  | VII          | 8.33         |        |     |      | 3.00   |
|                | 19     | 5.12            | 7a+ | VII+         | 8.66         |        |     |      | 3.25   |
|                | 20     | 5.12            | 7b  | VII          | 8.66         |        |     |      | 3.50   |
|                | 21     | 5.12            | 7b+ | VII+         | 9.00         |        |     |      | 3.75   |
|                | 22     | 5.13            | 7c  | VII          | 9.33         |        |     |      | 4.00   |
|                | 23     | 5.13            | 7c+ | IX           | 9.66         |        |     |      | 4.25   |
|                | 24     | 5.13            | 7c+ | IX           | 10.00        |        |     |      | 4.50   |
|                | 25     | 5.13            | 8a  | IX           | 10.00        |        |     |      | 4.75   |
|                | 26     | 5.14            | 8a+ | IX           | 10.33        |        |     |      | 5.00   |
|                | 27     | 5.14            | 8a+ | XI           | 10.66        |        |     |      | 5.25   |
|                | 28     | 5.14            | 8a+ | XI           | 11.00        |        |     |      | 5.50   |
|                | 29     | 5.14            | 8a+ | XI           | 11.33        |        |     |      | 5.75   |
|                | 30     | 5.15            | 9   | XI           | 11.66        |        |     |      | 6.00   |
|                | 31     | 5.15            | 9a  | XI           | 12.00        |        |     |      | 6.25   |
|                | 32     | 5.15            | 9a+ | XII          | 12.00        |        |     |      | 6.50   |

Note: IR CRA 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, and Durschi (1993), Benge and Raleigh (1995), Draper et al. (2011b), Schöffl et al. (2010), BMC (2007), Rockfax (n.d.), The American Alpine Club (2012).
ascended between 5 and 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 as 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 I 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 (Baláš, Pecha, Martin, & Cochrane, 2012; Donath, Roechner, Schöffl, & Gabriel, 2013; Fanchini, Violette, Impellizzeri, & Maffioletti, 2013; Fryer, Dickson, Draper, Blackwell, & Hillier, 2012; Green, Draper, & Helton, 2013; Schoeffl et al., 2004; Schöffl, Hoffmann, & Küpper, 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 I relates to their highest self-reported redpoint ascent. A
accurate assessment of their ability? Drum (2014) stated, would making a successful ascent of a redpoint, from the German rotpunkt, refers to a successful lead climb ascent, without weighting the rope, of a 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 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?

Table I 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. The research is designed to identify valid and reliable measures of climbing ability and to examine the extent to which these can be utilised together to create a more objective measure of climbing ability. 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 I, has been developed to support a common approach to statistical analyses. In addition, the ability grouping nomenclature also detailed in Table I, 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 I for statistical analysis and classification of the climbers in their studies.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

Amca, A. M., Vigouroux, L., Aritan, S., & Bertron, E. (2012). Effect of hold depth and grip technique on maximal finger forces in rock climbing. *Journal of Sports Sciences*, 30, 669–677. doi:10.1080/02640414.2012.658845

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

Baláš, J., Panáčková, M., Strejcová, B., Martin, A. J., Cochrane, D. J., Kaláb, M., & Draper, N. (2014). Performance evaluation of the machine learning algorithms used in inference mechanism of a medical decision support system. *The Scientific World Journal*, 2014(2), 1–15. doi:10.1155/2014/678387

BMC. (2007). *A brief explanation of UK traditional climbing grades.* [online]. Retrieved November 15, 2014, 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, 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, 406–414. doi:10.1111/j.1600-0838.2011.01399.x

Draper, N., Brent, S., Hodgson, C., & Blackwell, G. (2009). FlexDrm, S. (2014). Personal communication. Retrieved November 23, 2014.

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

Draper, N., Dickson, T., Blackwell, G., Fryer, S., Priestley, S., Winter, D., & Ellis, G. (2011b). Self-reported ability assessment in rock climbing. *Journal of Sports Sciences*, 29, 851–858. doi:10.1080/02640414.2011.565362

Drum, S. (2014). Personal communication. Retrieved November 25, 2014.

Espósito, 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, 81–92.

Fanchini, M. (2014). Personal communication. Retrieved September 23, 2014.

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

Folkli, A. K. (2013). Characterizing the consequences of chronic climbing-related injury in sport climbers and boulderers. *Wilderness & Environmental Medicine*, 24, 153–158. doi:10.1016/j.wem.2012.11.010.

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*, 22, 645–650. doi:10.1111/j.1600-0838.2011.01432.x

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, 301–309.

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, 499–505.

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*, 78, 557–565. 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, 670–675. 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, 2296–2307.

Limonta, E., Cè, E., Veicsteinas, A., & Espósito, F. (2009). Force control during fatiguing contractions in elite rock climbers. *Sport Sciences for Health*, 4, 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, 413–426. doi:10.1016/S0925-9661(07)00026-3

MacLeod, D., Sutherland, D. L., Buntin, L., Whittaker, A., Aitchison, T., Watt, I., & Bradley, J. (2007). Physiological determinants of climbing-specific finger endurance and sport rock climbing performance. *Journal of Sports Sciences*, 25, 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, 231–238. doi:10.2478/v10036-009-0036-z

Morenas Martín, J., Del Campo, V. L., Leyton Román, M., Gómez-Valadéz 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, 1713–1721. 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*, 73–76.
Benge, M., & Raleigh, D. (1995). *Rock: Tools and technique*. Carbondale, CO: Elk Mountain Press.
Rockfax. (n.d.). Grade conversions.[online]. Retrieved November 15, 2014 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*, 422–425. doi: 10.1136/bjsm.2002.003996
Schoeffl, V., Morrison, A., Hefti, U., Ulrich, S., & Küpper, T. (2010). The UIAA medical commission injury classification for mountaineering and climbing sports. *Wilderness & Environmental Medicine, 22*, 46–51.
Schoeffl, 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, 24*, 187–194. doi:10.1016/j.wem.2013.03.020
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*, 687–693. doi:10.1007/s00421-010-1685-2
The American Alpine Club. (2012). *The American Alpine Journal*. Canada: The American Alpine Club.
Watts, P. B. (2004). Physiology of difficult rock climbing. *European Journal of Applied Physiology, 91*, 361–372. 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*, 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, 49*, 44–50. 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, 38*, 21–33. doi:10.1080/14927713.2014.932970