Journal of Sports Sciences
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/rjsp20

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Available online: 13 Apr 2011

To cite this article: Nick Draper, Tabitha Dickson, Gavin Blackwell, Simon Fryer, Sefton Priestley, David Winter & Greg Ellis (2011): Self-reported ability assessment in rock climbing, Journal of Sports Sciences, 29:8, 851-858

To link to this article: http://dx.doi.org/10.1080/02640414.2011.565362

Journal of Sports Sciences, May 2011; 29(8): 851–858

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Self-reported ability assessment in rock climbing

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(Accepted 18 February 2011)

Abstract
Level of ability within rock climbing is generally expressed in terms of a ''best ascent'', rated using various grading systems within the sport. The most common method of obtaining this information is via self-report. The aim of this study was to examine the validity of self-reported climbing grades. Twenty-nine competitive rock climbers (17 males, 12 females) were first asked to report their current (defined as within the last 12 months) best on-sight lead ascent grade (Aus/NZ). The participants then climbed a specifically designed indoor route, under on-sight conditions (one attempt, no route practice or preview), to obtain an assessed grade. The route increased in difficulty, and was such that the distance achieved by the climber corresponded to a particular grade. The mean ($\pm$standard deviation) self-reported and assessed grade was 22.6 ± 3.4 and 22.0 ± 3.0 (Aus/NZ) respectively. Despite slight over- and underestimations in males and females respectively, there was no statistically significant difference between self-reported and assessed on-sight climbing grades. The results of this study suggest that self-reported climbing grades provide a valid and accurate reflection of climbing ability.

Keywords: *Self-report, rock climbing, grade of climb*

Introduction

The increasing popularity of rock climbing as not only a recreational pursuit, but also as a competitive sport is evident through the growth of its scientific research base. Initially, climbing research focused on the reporting of injuries as a result of participation in the sport (incidence rates and anatomical location) and the collection of physiological and anthropometric data (Bollen, 1988; Bollen & Gunson, 1990; Draper, Bird, Coleman, & Hodgson, 2006; Grant, Hasler, Davies, Aitchison, & Wilson, 2001; Grant, Hynes, Whittaker, & Aitchison, 1996; McMorris et al., 2006; Mermier, Robergs, McMinn, & Heyward, 1997; Morrison & Schoffl, 2007; Sheel, Seddon, Knight, McKenzie, & Warburton, 2003; Wall, Starek, Fleck, & Byrnes, 2004; Watts, Martin, & Durtschi, 1993; Wright, Royle, & Marshall, 2001). More recently, rock climbing has been investigated as not only a physical and technical sport, but as a mentally demanding activity (Giles, Rhodes, & Taunton, 2006; Goddard & Neumann, 1993; Watts, 2004). It is becoming increasingly clear that, alongside the skilful aspects of the sport, both psychological and physiological parameters play a crucial role in determining performance. As a result, researchers have begun to investigate psychological aspects and their interaction with physiological demands, introducing a cross-disciplinary approach (Draper, Jones, Fryer, Hodgson, & Blackwell, 2008; Draper, Jones, Fryer, Hodgson, & Blackwell, 2010; Hardy & Hutchinson, 2007; Hodgson, Draper, McMorris, Jones, Fryer, & Coleman, 2009; Llewellyn & Sanchez, 2008; Sanchez, Boschker, & Llewellyn, 2010).

Assessment and categorization of rock climbing ability present some difficulties for research and comparative purposes due to the nature of the sport (Morrison & Schoffl, 2007). Climbing involves ascending routes on different artificial or rock surfaces, indoors and outdoors. Climbing routes are subjectively graded and the grading system employed often varies between countries. A comparison of some commonly used grading systems is shown in Table I. These various grading systems are widely used as an indicator of performance and to discriminate between ability groups in rock climbing studies (e.g. Bertuzzi, Franchini, Kokubun, & Kiss, 2007; Brent, Draper, Hodgson, & Blackwell, 2009; Grant et al., 2001; Janot, Steffen, Porcari, & Maher, 2000; Wall et al., 2004).

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ISSN 0264-0414 print/ISSN 1466-447X online
DOI: 10.1080/02640414.2011.565362

Table I. A comparison of international climbing grades.

YDS (USA)	British Tech/Adj		French	UIAA	Ewbank (Australia, NZ, and South Africa)
5.2			1	I	
5.3			2	II	11
5.4			3	III	12
5.5	4a	VD	4	IV	12
5.6		S	5a	V+	13
5.7	4b	HS	5b	VI−	14
	4c				15
5.8		VS	5c	VI	16
5.9	5a	HVS	6a	VI+	17
5.10a		E1	6a+	VII−	18
5.10b	5b		6b	VII	19
5.10c		E2	6b+	VII+	20
5.10d	5c		6c		21
5.11a		E3	6c+	VIII−	22
5.11b			6c+	VIII−	23
5.11c	6a	E4	7a	VIII	24
5.11d			7a	VIII	
5.12a		E5	7a+	VIII+	25
5.12b	6b		7b		26
5.12c		E6	7b+	IX−	27
5.12d	6c		7c	IX	28
5.13a		E7	7c+	IX+	29
5.13b			8a		
5.13c	7a		8a+	X−	30
5.13d		E8	8b	X	31
5.14a			8b+	X+	32
5.14b	7b		8c		33
5.14c		E9	8c+	XI−	34
5.14d	7c		9a	XI	35
5.15a			9a+	XI+	
5.15b			9b		

In these studies, climbing grade performance has been used as a key grouping variable for subsequent analysis. Although the ambiguity of grading systems can be addressed with the use of grade conversion tables readily available in climbing literature today (Lee, 2001; Main & Wethey, 2004; Peter, 2004), obtaining an observed and assessed grade for individual climbers is rather more problematic.

Assessing climbing ability during competition generally involves competitors being allocated one preview and one attempt on a route. The height the climber achieves determines the number of points awarded for the climb, with the climb increasing in difficulty as the climber ascends (IFSC, 2010). Although this method is widely accepted as competition format and provides a good measure of climbing ability, it is difficult to apply to a research context due to time constraints, participant availability, and the possible additional physiological demands over and above the protocol for the main research project. Most rock climbing studies have instead employed a self-report method of measurement as a convenient and practical solution to the requirement (see Table II).

The validity of self-report questionnaires depends on the respondent's ability to accurately assess and recall previous experience (Mikkelsson, Kaprio, Kautiainen, Kujala, & Nupponen, 2004). In the context of climbing, this is in relation to previous climbing ascents at different grades. Due to the nature of the sport, climbers are regularly exposed to grades as they are considered the primary indicator of performance and ability (Giles et al., 2006). Rock climbers habitually place themselves on climbing grade scales and use grade categories for current and future performance targets and are therefore aware of their use from initial experiences, making their use as a self-report measure appear well justified.

In the interest of determining how extensive the use of self-reported climbing grades is within current climbing research, we reviewed 31 climbing-related studies from various fields of research (e.g. psychology, physiology, biomechanics, injury) from the year 2000 onwards (Table II). Particular attention was paid to the participant group, self-report method, and grades obtained for each of these studies. While previous researchers have used a variety of grading systems for gauging ability via self-reported grades, it was found that the method/questions employed vary. This would appear to be due to the different styles and categories of ascent within rock climbing, namely bouldering, top roping, and leading. Bouldering is a style of rock climbing undertaken without a rope and is normally limited to very short climbs over a landing mat so that a fall will not result in serious injury (Michailov, Mladenov, & Schöffl, 2009). It is typically practised on large natural boulders or artificial boulders in gyms and outdoor urban areas. Top roping is where the safety rope is anchored above the climber at all times and is generally used with beginner climbers (Peter, 2004). Lead climbing in contrast is where the climber clips the rope to anchors or runners on the climb at various intervals (Richardson, 2001).

Although self-reported grades for lead climbing ability appear to be the most prominent within previous research, there are some inconsistencies as to whether redpoint or on-sight grades are used. A redpoint ascent is generally classified as a clean lead climb (without fall or weighting the rope) after having had practice of the route. The practice is generally completed either by leading with frequent rests on the rope, or by top roping. On-sight climbing refers to the clean ascent of a route first time without inspection or prior knowledge. Based on these discrepancies between studies, it would appear that there is no "gold standard" for obtaining self-reported climbing grades, and to date no work has been completed to validate self-reported ability with respect to rock climbing research. Therefore, the aim of this study was to examine the validity of

Table II. Summary of self-report methods and reported grades in rock climbing studies beyond the year 2000.

Study	Participants	Climbing grades (converted to Aus/NZ)
Janot et al. (2000)	Beginner and recreational	Not specified
Mermier et al. (2000)	Mixed ability	Male: mean = 21, range = 16–32
		Female: mean = 17, range = 13–27
Grant et al. (2001)	Elite and recreational	Traditional
		Elite 17+
		Recreational 13–17
Noé et al. (2001)	International competitors	Not specified
Wright et al. (2001)	Previous indoor experience	Not specified
Grant et al., 2003)	Intermediate	≥20
Quaine et al. (2003)	Elite	Not specified
Sheel et al. (2003)	Experienced competitive climbers	On-sight 26–34
Watts et al. (2003)	Experienced junior competitive climbers	Redpoint 25
Schöffl et al. (2004a)	High-level climbers	Redpoint: mean = 30, range = 29–32
Schöffl et al. (2004b)	Junior national team and recreational	Redpoint
		Elite 24–30
		Recreational 18
Wall et al. (2004)	Moderate, intermediate, and expert	Not specified
de Geus et al. (2006)	Competitive climbing experience	On-sight 26–30
Draper et al. (2006)	Recreational	Not specified
Ferrand et al. (2006)	Junior elite	26
Noé (2006)	International competitors	Not specified
Schöffl et al. (2006)	Not specified (rock climbers)	Redpoint 25
		On-sight 23
Bertuzzi et al. (2007)	Elite (top ten national ranking) and recreational	Elite 28–33
		Recreational 20–24
Hardy and Hutchinson (2007)	Experienced rock climbers	Traditional 16–25
MacLeod et al. (2007)	Intermediate	On-sight: mean = 25, range = 21–28
(Schöffl et al. (2007)	Junior national team and recreational	Redpoint
		Elite 28
		Recreational 18
Schweizer et al. (2007)		Redpoint 25
	Not specified (rock climbers)	On-sight 22
		Boulder 21
Draper et al. (2008)	Intermediate	Traditional 13–16
Llewellyn and Sanchez (2008)	Not specified (rock climbers)	20
Watts et al. (2008)	Experienced climbers	23
Brent et al. (2009)	Novice, intermediate, advanced, and elite	21
Espana-Romero et al. (2009)	High-level sport climbers	On-sight: Male = 30, Female = 25
Heyman et al. (2009)	Competitive club level	21–27
Michailov et al. (2009)	World Cup competitors	Boulder: Male = 33, Female = 30
		On-sight: Male = 32, Female = 28
		Redpoint: Male = 34, Female = 30
Sanchez et al. (2010)	Elite (Belgian climbing championship)	27–32
Draper et al. (2010)	Intermediate	Traditional 13–18

Note: Climbing grades refer to lead ascents unless otherwise stated.

self-reports of climbing ability through the use of climbing grades. To do this, the climbers' self-reported grades were compared with those obtained via an assessed climb.

Methods

Participants

The participants consisted of 29 competitive climbers (17 males, 12 females) who were competing at regional, national, and international levels and had been involved in the sport for 2–5 years (mean ± *s*: 3.5 ± 1 years). The participants' mean age, mass, height, and percentage body fat as measured by bioelectrical impedance analysis (In body 230, Biospace, Korea) were 24.1 ± 8.2 years, 64.4 ± 10.4 kg, 1.70 ± 0.08 m, and 17.4 ± 7.5% respectively. The mean self-reported climbing grade (highest on-sight lead ascent in the past 12 months) was 22.6 ± 3.4 (Aus/NZ). After being informed of his or her right to terminate participation at any stage, each climber provided written informed consent and completed a health history questionnaire before testing began. The study was conducted with institutional ethics approval.

Self-reported grade

To assess the validity of self-reported climbing grades, participants were asked to report their current perceived grade. This was defined as the most difficult on-sight lead ascent achieved in the current year (past 12 months). As described previously, the term ''on-sight'' is used within climbing to denote the completion of a route on first attempt without prior instruction, knowledge or practice of the route. Grades were reported using the Aus/NZ grading system. This grading scale was selected not only because it was familiar to the participants, but also because the numerical scale can be used in statistical analysis without the need for conversion. This has been necessary in previous research when using other grading systems such as the International Mountaineering and Climbing Organization (UIAA) and French rating (Michailov et al., 2009; Schöffl, Einwag, Strecker, & Schöffl, 2006; Schöffl, Hochholzer, & Imhoff, 2004a; Watts et al., 1993)

Climbing routes and measurement

To gain an accurate grading for participants and assess their ability via an observed assessed climb, a specific route was devised. The route was a sport lead set on an artificial indoor climbing wall under the supervision of four of the researchers. The route involved ascent of an 8-m vertical section that led to a 6-m roof section and onto a final 5-m vertical section, requiring 19 m of climbing in total for a complete ascent. During the ascent, the climbers could use the prescribed (colour-coded) holds or the natural features on the wall surface to make progress on the climb. The climbing holds were made from moulded resin (Uprising Ventures Ltd., Christchurch, New Zealand). The research team consisted of individuals with 5–20 years of experience in climbing, instructing, route setting, and the manufacture of climbing-specific apparatus. The route was modelled on those that are used in competitive climbing. The distance ascended by the climber corresponded to a climbing grade (Aus/NZ) agreed upon by those responsible for setting the route, with the climb increasing in difficulty as the climber progressed. The grade ascribed to each climber was dictated by the maximum point reached on the route before failure (fall).

Warm-up

Each climber was required to follow a climbing-specific warm-up before their attempt on the designated route. The prescribed warm-up was adapted from methods previously set out by Gresham (2007), Binney and McClure (2006), and Tenke and Higgins (1999). The warm-up began with 5 min of light aerobic exercise, walking, and jogging. This was followed by 5 min of mobilizing exercises. The climbers then completed light climbing for 10 min. The warm-up was conducted away from the assessed route to avoid any preview or knowledge of the route, as this would contravene the on-sight condition.

Procedure

Climbers were first asked to report their current on-sight climbing grade (Aus/NZ) as defined previously. Subsequent to this participants were informed of the nature of the climb (i.e to climb as far as possible) and completed the prescribed warm-up. Participants were permitted to use their personal climbing equipment (harness, climbing shoes, hardware, and chalk) so as to maintain personal climbing patterns. Before testing the participants were not informed of the corresponding levels of difficulty along the route and were neither allowed to physically rehearse nor observe others using the route. Each climber was allowed one attempt at the route with the furthest point reached noted and translated into a corresponding assessed grade (Aus/NZ).

Statistical analyses

All variables were assessed for normality of distribution using the one-sample Kolomogorov-Smirnov goodness-of-fit test before any further statistical analysis. To determine the validity of self-reported climbing grades, paired samples *t*-tests were used to examine whether there was a significant difference between self-reported and assessed grades. The limits of agreement method proposed by Altman and Bland (1983) and advocated by Nevill and Atkinson (1997) for a sports science context was used to confirm agreement between self-reported and assessed climbing grades. A more detailed explanation of the method is provided by Bland and Altman (1999). In addition, regression modelling was employed to identify the predictive potential of self-reported grades. These were calculated using the self-reported current grades and assessed grades. All statistical analyses were performed using Microsoft Excel 2007 and SPSS 17.0 for Windows. Statistical significance was set at $P < 0.05$ (two-tailed) for all inferential tests.

Results

Results of the Kolomogorov-Smirnov test indicated that all variables displayed normality of distribution. The mean grades for self-reported and assessed ability are displayed in Table III.

Paired samples *t*-tests revealed no significant difference between self-report grade and assessed grade in both males ($t_{15} = 1.208$, $P = 0.246$) and females ($t_8 = 1.357$, $P = 0.212$). The limits of agreement plot for self-reported and assessed climbing grades is given in Figure 1. The Bland and Altman plot indicated relatively close agreement between the two assessment methods, with the standard deviation of the differences being $\pm$ 1.8 grade points.

The regression model for self-reported climbing grades is presented in Figure 2. The regression equation for the model was: $y = 0.73x + 5.78$ ($R^2 = 0.72$, $P < 0.0005$).

Discussion

In this study, we sought to identify whether self-reported climbing grades corresponded to actual climbing ability, measured via an assessed climb. This was done to examine the validity of self-report grades and their use in past and future research. Results indicated that there was no statistically significant difference between self-reported on-sight (completion of a route on first attempt without prior instruction, knowledge or practice) climbing grades and assessed climb grade in both men and women. The ability of the climbers to accurately report personal climbing grades may be attributed to the emphasis placed on grades and performance within rock climbing. As stated previously, climbers are immersed in grading criteria and difficulty ratings in their sport. This may serve to reinforce their awareness of their ability on a regular basis.

Our data suggest the male climbers in this study had a tendency to slightly overestimate their ability (self report) when compared with an assessed grade (Table III). This could be due to individuals wishing to cast themselves in a more complementary light, and therefore reporting grades that appear more favourable. This response has been cited as a possibility in several studies of self-report methods (Jones, Knapik, Sharp, Darakjy, & Jones, 2007; Niedhammer, Bugel, Bonenfant, Goldberg, & Leclerc, 2000; Palta, Prineas, Berman, & Hannan, 1982; Spencer, Appleby, Davey, & Key, 2007). In contrast, female climbers appeared to underestimate slightly self-reported grades, perhaps being unwilling to rate themselves at the more difficult end of their potential ability. Sulheim and colleagues (Sulheim, Ekeland, & Bahr, 2007) also noted a similar trend among female skiers when asked to self-estimate skiing ability, attributing the tendency to a modest attitude. As can be seen from Figures 1 and 2, there was close agreement between reported and assessed climbing grades for most climbers, although one male climber reported his climbing grade at 30, but was assessed at 24 (NZ grade). This individual had recovered from an injury some months before, felt he was recovered, but perhaps had not in this context recovered as much as he perceived. This might need to be taken into account for future research when self-report climbing grades are reported. Even with this data point removed, however, the male climbers in this study slightly over-reported their climbing ability (mean overestimation of grade = +0.3) compared with their female counterparts (mean underestimation of grade = –0.44). Despite the slight discrepancies, differences between self-reported and assessed grades for the male and female climbers in this study were minimal.

Table III. Self-reported and assessed climbing grades (Aus/NZ) (mean $\pm$ *s*).

	Climbing grade	
	Self-reported	Assessed
Males ($n = 17$)	23.9 $\pm$ 2.4	22.9 $\pm$ 2.7
Females ($n = 12$)	20.1 $\pm$ 3.7	20.7 $\pm$ 3.1
Total ($n = 29$)	22.6 $\pm$ 3.4	22.0 $\pm$ 3.0

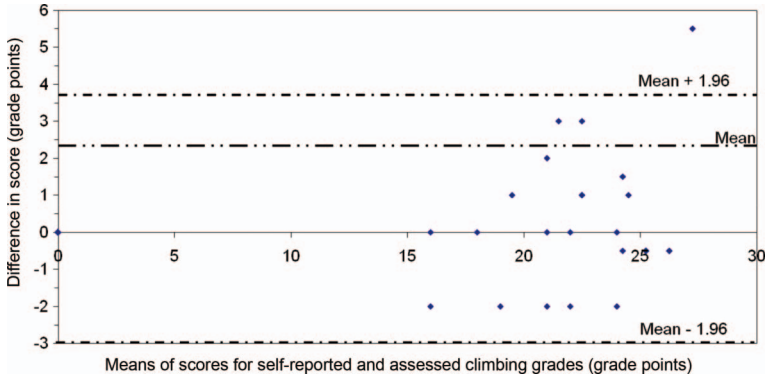

Figure 1. Limits of agreement for self-reported climbing ability and assessed climbing grade.

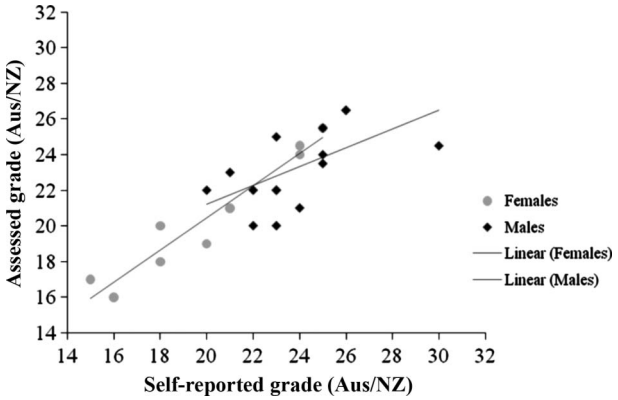

Figure 2. Regression model for self-reported climbing ability using self-reported climbing grade against assessed climbing grade.

Self-report climbing grades, as an estimation of climbing ability, have been reported previously, but the style of ascent (on-sight lead, redpoint, top-rope) has varied between studies (Grant et al., 2001; Mermier, Janot, Parker, & Swan, 2000; Schöffl et al., 2006). While the current study focused on the validity of self-reported grades with respect to on-sight sport lead ascents, the use of self-report would be advantageous in reporting grades for other styles of ascent, in order to gain a better understanding of ability. Michailov et al. (2009), Schoffl et al. (2006), and Schweizer and colleagues (Schweizer, Schneider, & Goehner, 2007) all obtained information regarding both redpoint and on-sight ability. Away from rock climbing, Mikkelsson et al. (2005) asked 64 participants to self-estimate, by questionnaire, their physical fitness (speed, endurance, strength, and flexibility). The volunteers (mean age 40 ± 1 years) then completed four fitness tests (number of jumps in 15 s, submaximal cycle erogmeter test, hand grip dynamometry, and sit-and-reach test) to assess each of the fitness parameters. The scores from the fitness tests were converted to Z-scores and summed. The responses were found to be correlated (Spearman rank correlation) with actual test results ($\rho = 0.54$), highlighting the ability to respond with moderate accuracy despite differences in the activity demands. In a similar fashion, it might be anticipated that the effectiveness and accuracy of self-reported grades will translate to other disciplines of climbing and styles of ascent, providing the climber is familiar with the grading system and terminology applied.

In addition to validating the use of self-reported climbing grades for the purpose of providing group averages, it must also be noted that accuracy of self-reported grades may aid in better classification of ability groups. A number of previous studies have identified groups as being either ''recreational'' or ''elite'', ''experienced'' or ''novice'' (Bertuzzi et al., 2007; Grant et al., 1996, 2001; Schöffl et al., 2004a; Schöffl, Hochholzer, Imhoff, & Schöffl, 2007). However, it would appear that there is a far greater range of experience and ability that warrants consideration. More recently, studies have attempted to classify climbers into three or four categories based on grades as an indicator of ability (Brent et al., 2009; Wall et al., 2004). The acceptance of self-reported grades as an accurate and valid measure may aid in better discrimination between differing levels of ability as opposed to a dichotomy. This improved definition would also assist in future comparisons between studies.

The results of this study suggest that the self-report method of obtaining on-sight grades for experienced climbers is accurate. The participants who took part in this study were all experienced climbers and therefore may not reflect the ability of novices to report climbing grades. Further investigation of differing ability levels, disciplines of climbing, and styles of ascent in relation to self-reported grades would be advantageous. In particular, the appropriateness and generalizability of the regression equation from this study would require independent confirmation prior to its application with other climbing groups. The ability of a climber and his or her level of experience might well influence the accuracy of self-reported climbing grades, and thus this requires further study.

Conclusion

A climber's level of ability is generally expressed in relation to a ''best ascent'' rated using various grading systems within the sport. The most common method of obtaining a graded level of ability for an individual within rock climbing research is via self-report. This method has been prevalent among rock climbing studies for a number of years. Self-report is widely accepted as a useful and practical solution to assessing or defining ability as opposed to an observed or assessed climb. Although widely used, no prior research had examined the validity of self-reported climbing grades. Despite the slight over- and underestimations for males and females respectively, our findings suggest that self-reported climbing grades provide valid and accurate reflections on climbing ability. The use of self-reported climbing grades in future studies appears well justified, as it may aid comparisons between studies and help to differentiate and categorize climbers of varying ability. The current study focused primarily on self-reported on-sight sport climbing grade; however, we suggest extending this to include different disciplines and styles of ascent, as this may be helpful in determining climbers' level of ability and in drawing comparisons between studies.

References

Altman, D. G., & Bland, J. M. (1983). Measurement in medicine: The analysis of method comparison studies. *The Statistician*, *32*, 307–317.

Bertuzzi, R., Franchini, E., Kokubun, E., & Kiss, M. (2007). Energy system contributions in indoor rock climbing. *European Journal of Applied Physiology*, *101*, 293–300.

Binney, D., & McClure, S. (2006). Aerobic and anaerobic power: Power endurance. *Climb*, *26*, 64–66.

Bland, J. M., & Altman, D. G. (1999). Measuring agreement in method comparison studies. *Statistical Methods in Medical Research*, *8*, 135–160.

Bollen, S. (1988). Soft tissue injury in extreme rock climbers. *British Journal of Sports Medicine*, *22*, 145–147.

Bollen, S., & Gunson, C. (1990). Hand injuries in competition climbers. *British Journal of Sports Medicine*, *24*, 16–18.

Brent, S., Draper, N., Hodgson, C., & Blackwell, G. (2009). Development of a performance assessment tool for rock climbers. *European Journal of Sport Science*, *9*, 159–167.

de Geus, B., Villanueva O'Driscoll, S., & Meeusen, R. (2006). Influence of climbing style on physiological responses during indoor rock climbing on routes with the same difficulty. *European Journal of Applied Physiology*, *98*, 489–496.

Draper, N., Bird, E. L., Coleman, I., & Hodgson, C. (2006). Effects of active recovery on lactate concentration, heart rate and RPE in climbing. *Journal of Sports Science and Medicine*, *5*, 97–105.

Draper, N., Jones, G., Fryer, S., Hodgson, C., & Blackwell, G. (2008). Effect of an on-sight lead on the physiological and psychological responses to rock climbing. *Journal of Sports Science and Medicine*, *7*, 492–498.

Draper, N., Jones, G., Fryer, S., Hodgson, C., & Blackwell, G. (2010). Physiological and psychological responses to lead and top rope climbing for intermediate rock climbers. *European Journal of Sport Science*, *10*, 13–20.

Espana-Romero, V., Porcel, F., Artero, E., Jimenez-Pavon, D., Sainz, A., Garzon, M. et al. (2009). Climbing time to exhaustion is a determinant of climbing performance in high-level climbers. *European Journal of Applied Physiology*, *107*, 517–525.

Ferrand, C., Tetard, S., & Fontayne, P. (2006). Self-handicapping in rock climbing: A qualitative approach. *Journal of Applied Sport Psychology*, *18*, 271–280.

Giles, L., Rhodes, E., & Taunton, J. (2006). The physiology of rock climbing. *Sports Medicine*, *36*, 529–545.

Goddard, D., & Neumann, U. (1993). *Performance rock climbing*. Mechanicsburg, PA: Stackpole Books.

Grant, S., Hasler, T., Davies, C., Aitchison, T., & Wilson, J. (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.

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., Shields, C., Fitzpatrick, V., Loh, M., Whitaker, A., Watt, I. et al. (2003). Climbing-specific finger endurance: A comparative study of intermediate rock climbers, rowers and aerobically trained individuals. *Journal of Sports Sciences*, *21*, 621–630.

Gresham, N. (2007). Training and technique for climbers of all levels. *Climber*, *12*, 78–80.

Hardy, L., & Hutchinson, A. (2007). Effects of performance anxiety on effort and performance in rock climbing: A test of processing efficiency theory. *Anxiety, Stress, and Coping*, *20*, 147–161.

Heyman, E., De Geus, B., Mertens, I., & Meeusen, R. (2009). Effects of four recovery methods on repeated maximal rock climbing performance. *Medicine and Science in Sports and Exercise*, *41*, 1303–1310.

Hodgson, C. I., Draper, N., McMorris, T., Jones, G., Fryer, S., & Coleman, I. (2009). Perceived anxiety and plasma cortisol concentrations following rock climbing with differing safety rope protocols. *British Medical Journal*, *43*, 531–535.

International Federation of Sport Climbing (IFSC) (2010). *International climbing competition rules*. Retrieved May, 2010, from http://www.ifsc-climbing.org/?category_id = 11.

Janot, J., Steffen, J., Porcari, J., & Maher, M. (2000). Heart rate responses and percieved exertion for beginner and recreational sport climbers during indoor climbing. *Journal of Exercise Physiology Online*, *3*, 1–7.

Jones, S., Knapik, J., Sharp, M., Darakjy, S., & Jones, B. (2007). The validity of self-reported physical fitness test scores. *Military Medicine*, *172*, 115–120.

Lee, A. (2001). *Climbing New Zealand; A crag guide for the travelling rock climber*. Nelson: Posing Productions.

Llewellyn, D., & Sanchez, X. (2008). Individual differences and risk taking in rock climbing. *Psychology of Sport and Exercise*, *9*, 413–426.

Main, L., & Wethey, T. (2004). *South Island rock*. Christchurch: NZAC.

MacLeod, D., Sutherland, D., Buntin, L., Whitaker, A., & Aitchison, T. (2007). Physiological determinants of climbing-specific finger endurance and sport rock climbing performance. *Journal of Sports Sciences*, *25*, 1433–1443.

McMorris, T., Harris, R. C., Swain, J., Corbett, J., Collard, K., Dyson, R. J. et al. (2006). Effect of creatine supplementation and sleep deprivation, with mild exercise, on cognitive and psychomotor performance, mood state, and plasma concentrations of catecholamines and cortisol. *Psychopharmacology*, *185*, 93–103.

Mermier, C., Janot, J., Parker, D., & Swan, J. (2000). Physiological and anthropometric determinants of sport climbing performance. *British Journal of Sports Medicine*, *34*, 359–366.

Mermier, C. M., Robergs, R. A., McMinn, S. M., & Heyward, V. H. (1997). Energy expenditure and physiological responses during indoor rock climbing. *British Journal of Sports Medicine*, *31*, 224–228.

Michailov, M., Mladenov, L., & Schöffl, V. (2009). Anthropometric and strength characteristics of world-class boulderers. *Medicina Sportiva*, *13*, 231–238.

Mikkelsson, L., Kaprio, J., Kautiainen, H., Kujala, U., & Nupponen, H. (2005). Associations between self-estimated and measured physical fitness among 40-year-old men and women. *Scandinavian Journal of Medicine and Science in Sports*, *15*, 329–335.

Morrison, A. B., & Schoffl, V. R. (2007). Physiological responses to rock climbing in young climbers. *British Journal of Sports Medicine*, *41*, 852–861.

Nevill, A. M., & Atkinson, G. (1997). Assessing agreement between measurements recorded on a ratio scale in sports medicine and sports science. *British Journal of Sports Medicine*, *31*, 314–318.

Niedhammer, I., Bugel, I., Bonenfant, S., Goldberg, M., & Leclerc, A. (2000). Validity of self-reported weight and height in the French GAZEL cohort. *International Journal of Obesity and Related Metabolic Disorders: Journal of the International Association for the Study of Obesity*, *24*, 1111–1118.

Noé, F. (2006). Modifications of anticipatory postural adjustments in a rock climbing task: The effect of supporting wall inclination. *Journal of Electromyography and Kinesiology*, *16*, 336–341.

Noé, F., Quaine, F., & Martin, L. (2001). Influence of steep gradient supporting walls in rock climbing: Biomechanical analysis. *Gait and Posture*, *13*, 86–94.

Palta, M., Prineas, R., Berman, R., & Hannan, P. (1982). Comparison of self-reported and measured height and weight. *American Journal of Epidemiology*, *115*, 223–230.

Peter, L. (2004). *Rock climbing: Essential skills and techniques.* Capel Curig, UK: Mountain Leader Training UK.

Quaine, F., Vigouroux, L., & Martin, L. (2003). Finger flexors fatigue in trained rock climbers and untrained sedentary subjects. *International Journal of Sports Medicine*, *24*, 424–427.

Richardson, A. (2001). *Rock climbing for instructors.* Marlborough, UK: The Corwood Press.

Sanchez, X., Boschker, M. S. J., & Llewellyn, D. J. (2010). Pre-performance psychological states and performance in an elite climbing competition. *Scandinavian Journal of Medicine and Science in Sports*, *20*, 356–363.

Schöffl, V., Einwag, F., Strecker, W., & Schöffl, I. (2006). Strength measurement and clinical outcome after pulley ruptures in climbers. *Medicine and Science in Sports and Exercise*, *38*, 637–643.

Schöffl, V., Hochholzer, T., & Imhoff, A. (2004a). Radiographic changes in the hands and fingers of young, high-level climbers. *American Journal of Sports Medicine*, *32*, 1688–1694.

Schöffl, V., Hochholzer, T., Imhoff, A., & Schöffl, I. (2007). Radiographic adaptations to the stress of high-level rock climbing in junior athletes. *American Journal of Sports Medicine*, *35*, 86–92.

Schöffl, V., Klee, S., & Strecker, W. (2004b). 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.

Schweizer, A., Schneider, A., & Goehner, K. (2007). Dynamic eccentric–concentric strength training of the finger flexors to improve rock climbing performance. *Isokinetics and Exercise Science*, *15*, 131–136.

Sheel, A., Seddon, N., Knight, A., McKenzie, D., & Warburton, D. (2003). Physiological responses to indoor rock-climbing and their relationship to maximal cycle ergometry. *Medicine and Science in Sports and Exercise*, *35*, 1225–1231.

Spencer, E., Appleby, P., Davey, G., & Key, T. (2007). Validity of self-reported height and weight in 4808 EPIC–Oxford participants. *Public Health Nutrition*, *5*, 561–565.

Sulheim, S., Ekeland, A., & Bahr, R. (2007). Self-estimation of ability among skiers and snowboarders in alpine skiing resorts. *Knee Surgery, Sports Traumatology, Arthroscopy*, *15*, 665–670.

Tenke, Z., & Higgins, A. (1999). *Warm-up and preparation for athletes of all sports.* Toronto: Sports Book Publishers.

Wall, C., Starek, J., Fleck, S., & Byrnes, W. (2004). Prediction of indoor climbing performance in women rock climbers. *Journal of Strength and Conditioning Research*, *18*, 77–83.

Watts, P. (2004). Physiology of difficult rock climbing. *European Journal of Applied Physiology*, *91*, 361–372.

Watts, P. B., Jensen, R. L., Gannon, E., Kobeinia, R., Maynard, J., & Sansom, J. (2008). Forearm EMG during rock climbing differs from EMG during handgrip dynamometry. *International Journal of Exercise Science*, *1*, 4–13.

Watts, P., Joubert, L., Lish, A., Mast, J., & Wilkins, B. (2003). Anthropometry of young competitive sport rock climbers. *British Medical Journal*, *37*, 420–424.

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

Wright, D. M., Royle, T. J., & Marshall, T. (2001). Indoor rock climbing: Who gets injured? *British Journal of Sports Medicine*, *35*, 181–185.