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Original Article

Design and validation of an observational instrument to assess the technical execution in top-rope climbing

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ABSTRACT

Hernández-Hernández, E., Caballero-Blanco, P., Gómez-Rodríguez, A., & Morenas-Martín, J. (2014). Design and validation of an observational instrument to assess the technical execution in top-rope climbing. *J. Hum. Sport Exerc., 9*(1), pp.111-123. The aim of this study was to design and validate an observational instrument to assess the technical execution in top-rope climbing. This observational instrument allows researchers to assess the progression of climbers in relation to the achievement of key aspects of climbing movements. Firstly, a review of the specialized literature was performed to establish a set of criteria for observation. Secondly, content validation was carried out through the agreement and consensus method among ten expert judges at the qualitative level (degree of understanding, appropriateness of wording, relevance of questions, etc.), and quantitative level (global assessment on a scale from 0 to 10). Thirdly, this instrument was applied to a sample of seven climbers on an indoor climbing wall. Reliability was calculated through the application of the test-retest method. The results indicated that the instrument has optimal levels of reliability and validity for evaluating the technical execution of beginning climbers. The instrument can be considered as a useful tool which could be applied by instructors and teachers for discriminating the learning stage in beginning climbers. **Key words**: SPORT CLIMBING, BEGINNING CLIMBERS, OBSERVATIONAL ANALYSIS, KEY ASPECTS, EVALUATION

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INTRODUCTION

Climbing is a physical activity that consists in ascending on a sloped wall. This activity involves physical and psychological components. Sport climbing is a style of climbing where the climber progresses through permanent anchors placed on the rock or on the climb wall with the main help of hands and feet, or other parts of the body. Sport climbing is the most popular modality of climbing for a wide range of persons (children, teenagers, adults) in recreational and competition activities (Bourne et al., 2011).

Performance in climbing largely depends on climber's physical capacity. During the ascension the efficiency depends on two components: a) physical components, in particular, muscular endurance and strength (Lopez-Rivera & González-Badillo, 2012), and b) technical components, in particular, the execution of climbing gesture (Winter, 2000). These two dimensions are present in the whole bibliography dealing with climbing performance. Indeed, an extensive review of the specific literature shows that numerous studies explain the climbing performance through physical components in conjunction with others parameters. Most of them stress the importance of endurance and different strength training methods (Cuadrado et al., 2007; Grant et al., 2003; Janot et al., 1999; Lopez-Rivera & González-Badillo, 2012; MacLeod et al., 2007; Schweizer et al., 2007) and physiological and psychological components (Billat et al., 1995; Draper et al., 2010; Janot et al., 2000; Jones et al., 2002; Pijpers et al., 2003; Sánchez et al., 2010).

In contrast, there are fewer studies focusing on technical components. In such instances, the technical execution is understood as the climber´s level and his/her experience (Bergua, 2009; Fuss & Niegl, 2012; Mace & Carroll, 1985; Nieuwenhuys et al., 2008; Russell et al., 2012), or is described through kinematics and biomechanical parameters (Quaine & Martin, 1999; Schweizer, 2001; Schweizer, & Hudek, 2011; Schweizer et al., 2007). Within this set of studies, only few authors centre on the climber´s execution considering the two extremities: arms and legs (De Benito et al., 2012), and none of them divide it into key aspects of the movement (Knudson & Morrison, 2002). At the end of the day, only De Benito et al. (2011) designed an instrument to measure the technical execution. In their following studies, these authors divided the execution of climbing movements into key aspects (De Benito et al., 2012), and subsequently, they described the rate of use of each extremity during the climbing phase (De Benito et al., 2013). In these studies, all participants were experienced climbers.

Lastly, other documents – such as handbooks and methods for beginners – provide valuable information about the technical base for the realization of climbing movements (Fontaine & Deconinck, 2005; Lourens, 2005; Testevuide, 2003; Winter, 2000). From this perspective, the technical execution is usually divided into: position of the arm, weight distribution between arms and legs, location of the feet in relation to the grip, location of the body regarding the vertical axis and the wall. Drawing on these findings, the aim of this study was to design and validate an observational instrument to assess the technical execution of beginning climbers in top-rope climbing.

MATERIAL AND METHODS

Participants

First of all, the content validation of the instrument was performed through the agreement and consensus method among ten expert judges. The expert judges were divided into two groups: a) five of them had a degree in Sport and Physical Education and at least five years of experience as teachers in adventure sports and school-to-work education; and b) five of them were B.A. in Sport and Physical Education and at least five years of experience in climbing. Secondly, the instrument was applied to a sample of seven students aged 12 (four girls and three boys) who were members of the Municipal school of climbing of Cortegana (Andalusia, Southwestern Spain). A voluntary informed consent was signed by their parents previously. Reliability was calculated by applying the test-retest method.

Design

On the one hand, validity refers to the degree to which a test measures what it is supposed to measure (Thomas & Nelson, 2007). The validity of contents was carried out through the agreement and consensus method among ten expert judges. The content validation of the instrument was established qualitatively as: a) the degree of understanding, b) the appropriateness of wording, and c) the relevance of questions. The content validation of the instrument was performed quantitatively as a global assessment on a scale from 0 to 10. Drawing on the proposal of Bulger & Housner (2007), items obtaining a value lower than 7 were eliminated. Items valued between 7 and 8 were modified, and items which scored more than 8 were accepted. On the other hand, reliability can be defined as the consistency of a measure (Thomas & Nelson, 2007). The reliability of this instrument was achieved applying the test-retest method through a pilot study.

Instruments

This observational instrument was supposed to allow assessing the technical execution of beginning climbers during their ascent. Such an assessment relied on the achievement of key aspects of climbing technique. The observer had to indicate with "yes" or "no" whether the beginning climbers met the conditions defined for each key aspect. Among them, five key aspects were assessed through a threefold scale (level 1, 2 or 3).

Procedures

The research design followed five steps (Carretero-Dios & Pérez, 2007). The first step consisted in designing a proposal for elaborating an observational instrument. A review of the major databases (SportDiscus®, PubMed, Web of Science, Google Scholar, Google Books, Sponet, and Dialnet) was realized. The key words used were: climbing, performance analyses, handgrips and evaluation. The titles and abstracts of the articles and the index of books were analyzed. As a result, it was observed that authors usually divided climbing movements into four positions: position of the arm, weight distribution between arms and legs, location of the feet regarding the grip, location of the body in relation to the vertical axis and the wall (Fontaine & Deconinck, 2005; Lourens, 2005; Testevuide, 2003; Winter, 2000). The initial proposal of observational categories was made following the criteria proposed by Anguera (2003) and Knudson & Morrison (2002). Afterwards, the instrument was tested on beginners on an indoor climbing wall using the top-rope technical.

Secondly, content validity was established through the agreement and consensus method among ten expert judges. Those experts were asked to evaluate different facets of the observational instrument. The third phase involved the analysis of expert judges' answers; all the aspects observed and criticized by the expert judges were modified. During the fourth phase the reliability was calculated by applying the test re-test method. A voluntary informed consent of the beginning climbers' parents was signed previously. The instrument was applied at two different moments with one week of difference (Baumgartner, 2000; Nevil, et al. 2001). As usually, the instrument was tested in the same conditions on an indoor climbing wall. Lastly, the fifth step consisted in analysing the results.

Statistical analysis

A descriptive analysis of the different variables was carried out. The degree to which test scores were consistent was obtained applying a Cronbach's alpha test of internal consistency. The Lowenthal value was taken as reference (Lowenthal, 2001).

RESULTS

As stated previously, the review of literature demonstrated that the majority of authors divided the climbing movements into four basic positions: position of the arms, weight distribution between arms and legs, location of the feet in relation with the grip, and location of the body vis-à-vis the vertical axis and the wall (Fontaine & Deconinck 2005; Lourens, 2005; Testevuide, 2003; Winter, 2000). In the final proposal sent to the experts, the repertoire of climbing movements also included other criteria focusing on the ascending and descending phases, and on the communication between climber and belayer (table 1). This instrument aimed to assess whether beginning climbers needed to improve some features of their technique of execution.

***Table 1**. Description of key aspects used by the instrument's design to assess the technical execution in top-rope climbing.*

Key aspects	Description
1) Use of three supporting points.	The climber uses at least three supporting points (two hands and one foot, or one hand and two feet) during the ascent.
2) Balanced position	The climber is balanced during the ascent. The center of gravity projection lies between the feet or on one of them.
3) Arms and legs action	The climber uses the arms for balancing during the ascension. The legs bear the most weight with a relevant role during the ascent.
4) Fluency during the ascent	The climber follows the route with fluency. He/she does not stay too much time in the same position.
5) Observation of the supporting points	The climber looks for a grip option before he/she makes the next movement during the ascent.
6) Grip	Look at the part of the hold gripped by the climber and indicate his/her technical level using the picture.
7) Feet´s supporting points	Look at the part of the foot used by the climber to step on the hold and indicate his/her technical level using the picture.
8) Interaction zone between hands and feet	Look at the extent between the hands and the feet of the climber and indicate his/her technical level using the picture
9) Displacement of the hip	Look at the displacement of the climber's hip compared with the vertical line of the feet and indicate his/her technical level using the picture.
10) Action line	Look at the action line between the hands and feet of the climber during the ascent and indicate his/her technical level using the picture.
11) Crossed force	The climber uses the opposite hands and feet (right hand with left foot, and *vice versa*) during the ascent.
12) Arms stretched	The climber keeps the arms stretched during the ascent.
13) Position and damping during a fall	The climber adopts a semi-flexed position and he/she puts his/her arms and legs in front of his/her body. The impact against the wall is limited by the use of the feets and hands. His/her back side is not in contact with the wall.

14) Descent of the route	The climber shouts to the belayer: "on belay!" The whole weight of the climber relies on the rope. The climber is ready for abseiling.
15) Climbing command	The climber communicates constantly with the belayer during the ascent. They use sentences as: "take" or "on belay!"

The expert judges suggested that the key aspects included in the instrument were relevant to assess the technique of beginning climbers. However, five parameters scored worse than the rest (items: 8, 9, 10, 11 y 13) and were eliminated. Expert judges explained that the reason was the difficulty to analyse those parameters only through observation (J2, J3, J6, J8, J9, and J10). For example, "a displacement of the hip" can be difficult to observe without a biomechanical analysis. Indeed, it can be interpreted in different ways by two observers. The aspects related to the "Position and damping during a fall" were also eliminated. Expert judge suggested that these features were not relevant in top-rope climbing since climbers are belayed. As a consequence, climbers cannot fall more than a short distance and they only realize a slight displacement with no flight (J2, J3, J5 and J10).

The expert judges noted that the instrument was appropriate and understandable. Table 2 displays the quantitative assessment for each aspect. The global assessment was 8.42. The global assessment without the eliminated parameters reached 8.9 (table 2). Experts also stressed the need to clarify expression for a better understanding. For example, a) the expression "looking at a grip" was replaced by the expression: "looking for a grip option" (judges 1 y 8); b) the expression "three supporting points" also included more information through the inclusion of the sentence "two hands and one foot or one hand and two feet" (judges 5 y 6); and eventually c) the expression "the weight should fall between the feet or on one of them" (judge 2) substituted for "the weight is on the centre of gravity projection".

Table 2. *Average results obtained by the instrument according to the expert judges' evaluation.*

Experts	J1	J2	J3	J4	J5	J6	J7	J8	J9	J10	Global assessment
Three supporting points	9	10	8	10	10	10	10	9	10	10	9.6
Action	No	No	No	No	No	No	No	No	No	No	
Balanced position	9	8	10	10	7	10	9	9	10	10	9.2
Action	No	No	No	No	Yes	No	No	No	No	No	
Arms and legs movements	9	10	10	10	10	10	10	9	10	9	9.7
Action	No	No	No	No	No	No	No	No	No	No	
Fluency during the ascent	9	7	8	7	8	10	7	9	8	10	8.3
Action	No	Yes	No	Yes	No	No	Yes	No	No	No	

Observation of the supporting points	7	10	10	10	10	9	7	7	8	9	8.7
Action	Yes	No	No	No	No	No	Yes	Yes	No	No	
Grip	9	7	7	10	10	8	8	9	7	9	8.4
Action	No	Yes	Yes	No	No	No	No	No	Yes	No	
Feet´s supporting points	8	8	9	10	10	9	8	8	7	9	8.6
Action	No	No	No	No	No	No	No	No	Yes	No	
Arms stretched	9	10	9	10	10	9	8	9	7	9	9
Action	No	No	No	No	No	No	No	No	Yes	No	No
Descent of the route.	9	10	9	10	7	10	10	9	10	10	9.4
Action	No	No	No	No	Yes	No	No	No	No	No	
Climbing command	9	10	8	10	8	10	7	9	10	10	9.1
Action	No	No	No	No	No	No	Yes	No	No	No	
Total											8.9

Results higher than 8 (items were not modified: no), results between 7 and 8 (items were modified: yes), results lower than 7 (items were eliminated: e)

Table 3 shows the reliability results for each observed item. The instrument achieved a high internal consistency with a value of 0.76. After that, the statistical test was repeated without the lower value. In this case, the instruments got a very high level of reliability (Lowenthal, 2001).with a value of 0.92 (table 4).

Table 3. *Reliability results obtained in test re-test.*

	Scale´s mean eliminating the element	Scale´s variance eliminating the element	Total correlation adjusted elements	Cronbach's alpha eliminating one elements
support_pre	28,1429	19,143	,967	,704
support_post	28,2857	20,571	,710	,726
balance_pre	28,2857	20,571	,710	,726
balance_post	28,2857	20,571	,710	,726
action_pre	28,1429	19,143	,967	,704
action_pos	28,0000	20,000	,767	,719
fluency_pre	28,2857	21,238	,551	,736
fluency_post	28,1429	19,143	,967	,704
observat_pre	28,1429	19,143	,967	,704

observat_post	28,1429	19,143	,967	,704
grip_pre	28,0000	27,000	-,600	,806
grip_post	28,1429	28,476	-,843	,819
feet_pre	27,7143	29,238	-,626	,844
feet_post	27,8571	31,476	-,790	,862
stretch_pre	28,0000	20,000	,767	,719
stretch_post	28,0000	20,000	,767	,719
descent_pre	28,0000	20,000	,767	,719
descent_post	28,0000	20,000	,767	,719
command_pre	28,1429	21,476	,442	,742
command_pos	28,1429	21,476	,442	,742

< 0.4 no unacceptable reliability; 0.41-0.6 poor reliability; 0.61-0.8 questionable to acceptable reliability; >0.8 good reliability, >0.9 excellent reliability. Value obtained by Lowenthal (2001)

Table 4. *Reliability results obtained in test re-test if one item was eliminated.*

	Scale´s mean eliminating the element	Scale´s variance eliminating the element	Total correlation adjusted elements	Cronbach's alpha eliminating one elements
support_pre	24.5714	32.286	.949	.909
support_post	24.7143	34.238	.675	.916
balance_pre	24.7143	34.238	.675	.916
balance_post	24.7143	34.238	.675	.916
action_pre	24.5714	32.286	.949	.909
action_pos	24.4286	32.619	.889	.910
fluency_pre	24.7143	34.571	.614	.918
fluency_post	24.5714	32.286	.949	.909
observat_pre	24.5714	32.286	.949	.909
observat_post	24.5714	32.286	.949	.909
grip_pre	24.4286	42.619	-.655	.946
grip_post	24.5714	44.619	-.920	.951
stretch_pre	24.4286	32.619	.889	.910
stretch_post	24.4286	32.619	.889	.910
descent_pre	24.4286	32.619	.889	.910
descent_post	24.4286	32.619	.889	.910
command_pre	24.5714	34.619	.545	.919
command_pos	24.5714	34.619	.545	.919

< 0.4 no unacceptable reliability; 0.41-0.6 poor reliability; 0.61-0.8 questionable to acceptable reliability; >0.8 good reliability, >0.9 excellent reliability. Value obtained by Lowenthal (2001)

DISCUSSION

The main aim of this study consisted in designing and validating an observational instrument to assess the technical execution in top-rope climbing. The objective was to build a specific tool able to discriminate the learning stage in beginning climbers, viz. to check if beginning climbers had a good command of the different techniques used in top-rope climbing. In addition, this proposal aimed to fill the gap of academic literature on inexpert climbers since the majority of scientific studies focus on top level climbing.

The references checked for this study demonstrated that most authors divided the climbing movements into four simple positions: position of the arms, weight distribution between arms and legs, location of the feet in relation to the grip, and location of the body regarding the vertical axis line and the wall (Fontaine & Deconinck, 2005; Lourens, 2005; Testevuide, 2003; Winter, 2000). Nevertheless, climbing does not allow isolating a series of muscles. Instead of this, climbing mobilizes large muscular groups. Consequently – and drawing on the proposal of De Benito et al. (2011, 2013) – features like the use of three supporting points, the arms and legs' movements, the fluency during the ascent, the interaction zone between hands and feet and the displacement of the hip were included in the roster of parameters composing the instrument.

The results of this study demonstrated that the designed instrument provided optimal levels of reliability and validity. This means the instrument can be implemented in other similar circumstances. This study used the same methodology than previous analyzes led in other fields like volleyball (Hernández-Hernández & Palao, 2012; 2013; Moreno et al., 2010), basketball (Ortega et al., 2008) and physical education lessons (Ortega et al., 2008; Wright & Craig, 2011). In general, expert judges made important contributions for improving the instrument. One of these suggestions proposed to eliminate three aspects of the instrument: the displacement of the hip, the interaction zone between hands or the feet, and the application of crossed force. The judges suggested that those aspects could only be observed through a biomechanical analysis. Furthermore, the judges concluded that their inclusion in the instrument could provoke divergent results among two observers. As a consequence, it could damage the psychometric properties of the instrument. For this reason it was decided to eliminate those aspects.

Others expert judges´ proposals consisted in eliminating the parameter referring to the body´s position and damping during a fall. Expert judges suggested that this aspect was not relevant in top-rope climbing because this modality limits fall flights. In top-rope climbing, the climber is always belayed by his/her climbing partner (Draper et al., 2010). In case of slip, the climber can only realize a slight displacement with no consequence (Fontaine & Deconinck, 2005; Testevuide, 2003). However, this affirmation cannot be discussed with others studies since reviewed analyses usually focus on top level climbers.

Lastly, expert judges suggested improving the clarity of expression of the observed parameters. These qualitative contributions were essential for improving the design of the instrument (Bulger & Housner, 2007; Carretero-Dios & Pérez, 2007; Padilla et al., 2007; Subramanian & Silverman, 2000; Wieserma, 2001) because they provided relevant information to modify or to eliminate the items (Dunn et al., 1999). The expert judges' contributions are included in the final version of the instrument (annex 1). The judges also considered this instrument as necessary while stressing the comprehensiveness and the difficulty to analyse each stage of the climber`s movements during the ascent. Finally, the climbers' technique was divided into ten key aspects which can be observed during the ascent. Thus, the final instrument is easy to apply in beginner's schools and others similar contexts.

The result of the reliability test showed a Cronbach's alpha value close to 0.8. This result clearly indicates that the instrument reached an acceptable reliability level (Lowenthal, 2001). This is a remarkable score considering this internal consistency test was used in other studies where the reliability of instruments had been accepted with values about 0.70 (Hernandez-Hernandez & Palao, 2013; Moreno et al., 2010). However, the level of reliability improved when one of the parameters was eliminated. As a consequence, the "feet´s supporting points" feature is an aspect that should not be included in the final instrument – contrary to the comments by Testevuide (2003). In those circumstances, this aspect must be reformulated for being part of the instrument.

CONCLUSIONS AND LIMITATIONS

The results indicated that the instrument to assess the technical execution in top-rope climbing has optimal levels of reliability and validity. Therefore, this instrument can be considered as a useful tool which could be applied by instructors and teachers for discriminating the learning stage in beginning climbers.

The main limitations of the study were: a) the absence of values of references about beginning climbers' technique, and b) the number of participants. Future studies dealing with that issue will have to increase the number of participants and observations. Furthermore, it could be interesting to apply this instrument on other surfaces like natural rock formations, and to design an instrument set that assesses others climbing´s aspects as the technique of the belayer, or the leading climber´s skills.

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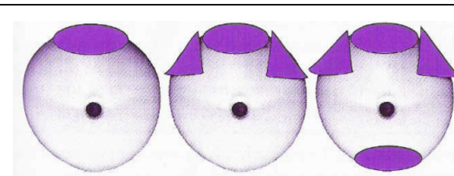
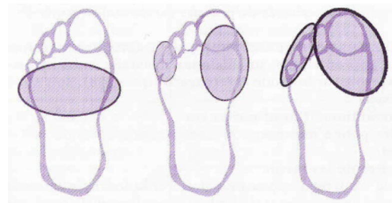
ANNEX 1. Final proposal of the instrument to assess the technical execution in top-rope climbing.

Instrument to assess the technical execution in top-rope climbing.	
1) Use of three supporting points**.**	The climber uses at least three supporting points (two hands and one foot, or one hand and two feet) during the ascent.
	(Yes) The climber uses at least three supporting points during the ascent.
	(No) The climber does not use at least three supporting points. Either he/she only uses the hands, or he/she uses one hand and one foot, or he/she keeps on his/her four extremities.
2) Balanced position**.**	The climber is balanced during the ascent. The centre of gravity projection lies between the feet or on one of them.
	(Yes) The climber is usually balanced. The centre of gravity projection lies between the feet or on one of them. (No) The climber is not balanced. The centre of gravity projection lies out of the feet area.
3) Arms and legs action**.**	The climber uses the arms for balancing during the ascension. The legs bear the most weight with a relevant role during the ascent.
	(Yes) The climber uses the arms for balancing during the ascension. The legs bear the most weight with a relevant role during the ascent.
	(No) The climber uses almost exclusively the arms during the progression. The weight bears on the arms and he/she does not use the feet.
4) Fluency during the ascent	The climber follows the route with fluency. He/she does not stay too much time in the same position.
	(Yes) The climber follows the route with fluency. He/she does not stay too much time on the same holds.
	(No) The rhythm of ascending is irregular. He/she spends a long time on the same holds, or he/she uses the same holds twice.
5) Observation of the supporting points**.**	The climber looks for a grip option before he/she makes the next movement during the ascent.
	(Yes) The climber usually looks for a grip option before he/she makes the next movement during the ascent. He/she keeps looking at the next hold until he/she finishes the movement. (No) The climber does not look for a grip option before he/she makes the next movement; or he/she feels for a grip without finish the ascending movement.
6) Grip	Look at the part of the hold gripped by the climber and indicate his/her technical level using the picture.
	Level 1 ( ) Level 2 ( ) Level 3 ( )
	
7) Feet´s supporting points	Look at the part of the foot used by the climber to step on the hold and indicate his/her technical level

	using the picture.
	Level 1 ( ) Level 2 ( ) Level 3 ( )
	
8) Arms stretched	The climber keeps the arms stretched during the ascent.
	(Yes) The climber keeps the arms stretched during the ascent. (No) The climber does not keep the arms stretched during the ascent.
9) Descent of the route.	The climber shouts to the belayer: "take!" The whole weight of the climber relies on the rope. The climber is ready for abseiling.
	(Yes) The climber shouts: "take". The whole weight of the climber relies on the rope. The climber is already for abseiling.
	(No) The climber does not shout: "on belay". His/her whole weight does not rely on the rope. The climber is not ready for abseiling.
10) Climbing command.	The climber communicates constantly with the belayer during the ascent, the descent and when he/she reached the top rope anchor. They use sentences as: "take!" or "on belay!"
	(Yes) The climber communicates constantly with the belayer during the ascent, the descent and when he/she reaches the top rope anchor. They use sentences as: "take!" or "on belay!" (No) The climber and the belayer do not communicate sufficiently during the ascent and when the climber reaches the top rope anchor.
Legend: The observer should indicate "yes" or "no" whether the beginning climbers met the conditions defined for each key aspect. It will be considered that a key aspect has been reached when the climber key aspects are marked as "yes" at least 70% of the time. Items 6 and 7 are assessed through a scale from 1 to 3.	