Evaluation of ergonomics of a new effort saving via-ferrata carabiner - child vs. adult use

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Received 20 March 2013; revised 18 May 2013; accepted 27 May 2013

Abstract

Despite via-ferrata (Klettersteig) climbing has become more and more popular, currently no appropriate safety equipment is available for lightweight climbers. A typical example of missing user friendliness for children is the via ferrata carabiner whose dimension – compared to customary adult equipment – and unlocking procedure might be inadequate for a child’s hand. A new designed effort saving via-ferrata carabiner (ERGOTEC, SALEWA Sportgeräte GmbH, Germany) has been evaluated with respect to ergonomics and user friendliness for both children and adults. Twelve adults (21 to 29 years) and twelve children and adolescents (7 to 15 years) tested a new effort saving via-ferrata carabiner ERGOTEC and two conventional carabiners – One-Touch (EDELRID GmbH & Co. KG, Germany) and ATTAC (SALEWA Sportgeräte GmbH, Germany). The activities produced by the flexors M. brachioradialis and M. flexor carpi ulnaris were measured in two loading situations by using Electromyography (EMG, Noraxon Inc., USA). With the new effort saving via-ferrata carabiner a reduction of muscle activity compared to the two conventional carabiners was observed for adults as well as for children and adolescents. However due to different hand anthropometry and muscle forces differences in operation and handling of the via-ferrata carabiners, i.e. the position of the transmission of the finger forces, were observed. To compensate the lower finger forces children use the advantage of a better lever arm for all three tested carabiners, i.e. the distance of the force transmission to the hinge joint increased. But with this position of the fingers it is difficult to mount the customary carabiners in the steel cable. With the design of the via-ferrata carabiner ERGOTEC a user friendly handling was observed also with the anthropometry of smaller child hands.

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Keywords: Climbing; via-ferrata; klettersteig; carabiner; electromyography

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1. Introduction

A via-ferrata or Klettersteig path is a protected climbing route in the mountains using a steel cable which runs along the route and is periodically fixed to the rock. In a via-ferrata route a climber can secure oneself to the cable by using specific safety equipment. Together with harness and helmet a special via-ferrata kit consists of lanyard, energy absorber and two carabiners.

But despite via-ferrata climbing has become increasingly popular by families with children, currently no specific safety equipment available for child use and the existing safety equipment for adults is not secure enough for child use. One well known problem herein is the inadequate test procedure specified in the European standard EN 958: “Mountaineering equipment – Energy absorbing systems for use in Klettersteig (Via-ferrata) climbing” [1]. The specified safety requirements for an energy absorbing system are only fulfilled for an 80 kg mass and a modification of the standard has to be carried out [2].

The requirements of via-ferrata carabiners (marked with a K in a circle) are specified in the European standard EN 12275: “Mountaineering equipment – Connectors – Safety requirements and test methods.” [3]. The minimum requirement of the static stiffness is 25 kN in longitudinal direction and 7 kN in transverse direction. A carabiner of category K allowing a larger opening compared to customary carabiners, i.e. a steel cable of diameter 21 mm has to be placed without impairment of the freely moving latch from closed to completely opened position (Fig. 1). In consequence the dimensions of the via-ferrata carabiners are larger compared to conventional carabiners.

![Fig. 1. Minimum geometric specification of a via-ferrata carabiner (category K) according to EN 12275](image)

A requirement according to EN 12275 is a automatic spring locking mechanism which has to be opened with one hand, but without a specification of a minimum or maximum spring stiffness of the locking mechanism. Resulting from the larger dimension – compared to customary adult equipment – and the unlocking procedure the via-ferrata carabiner might be inadequate for a child’s hand and a typical example of missing user friendliness for children. In difference to studies comparing the Electromyograms of the finger flexors and extensors of elite climbers and non-climbers no comparison on muscle forces of climbers of different ages are available in the literature [4,5]. Therefore a new designed effort saving via-ferrata carabiner (ERGOTEC, SALEWA Sportgeräte GmbH, Germany) has been evaluated with respect to ergonomics and user friendliness for both children and adults.
2. Method

The new effort saving via-ferrata carabiner ERGOTEC was compared to two customary carabiners One-Touch (EDELRID GmbH & Co. KG, Germany) and ATTAC (SALEWA Sportgeräte GmbH, Germany) (Fig. 2).

Fig. 2. Tested carabiners (closed and opened): left: ERGOTEC (SALEWA Sportgeräte GmbH, Germany); middle: ATTAC (SALEWA Sportgeräte GmbH, Germany); right: One-Touch (EDELRID GmbH & Co. KG, Germany)

The muscle activities produced by the flexors M. brachioradialis and M. flexor carpi ulnaris of n = 12 adults (21 to 29 years) (test group A) and n = 12 children and adolescents (7 to 15 years) (test group C) were measured by using Electromyography (EMG, Noraxon Inc., USA) during following two loading situations:

1. A periodic loading, in which the test persons sat on a chair with the elbow on the table and pressed the carabiners while a metronome set the pace. The mean muscle activity of five representative maximum values was evaluated.
2. A realistic practice at a climbing wall, in which the mean muscle activity in each of three runs with four compressions of the carabiners was evaluated.

The overall mean values of the muscle activities were calculated for both test groups. The effect of the new effort saving carabiner was evaluated by a comparison of the measured muscle activities with the two customary carabiners.

3. Results

3.1. Electromyography with new carabiner ERGOTEC compared to customary carabiner ATTAC

Figures 3 and 4 show the individual effort savings with the new carabiner ERGOTEC normalized on the muscle activity measured with the customary carabiner ATTAC. During the periodic loading a decrease in the muscle activities of both M. brachioradialis and M. flexor carpi ulnaris was observed for n = 7 adults and n = 8 children/adolescents (no results for periodic loading of test person C8 available). An increase of the activities of both muscles was shown only for n = 2 adults and no children/adolescents. During the simulated realistic practice a decrease in the muscle activities of both M. brachioradialis and M. flexor carpi ulnaris were observed for n = 9 adults and for all n = 12 children/adolescents. Only for the M. brachioradialis a small increase of the muscle activity were observed for three adult test persons (A3, A9, A11).
3.2. Electromyography with new carabiner ERGOTEC compared to customary carabiner One-Touch

Figures 5 and 6 show the individual effort savings with the new carabiner ERGOTEC normalized on the muscle activity measured with the customary carabiner One-Touch. During the periodic loading for \( n = 10 \) adults and \( n = 11 \) children/adolescents (no results for periodic loading of test person C8 available) a decrease in the muscle activities of both M. brachioradialis and M. flexor carpi ulnaris was observed. An increase of the activities of both muscles was shown only for \( n = 2 \) adults (for M. flexor carpi ulnaris of test person A10 and M. brachioradialis of test person A8). During the simulated realistic practice a decrease in the muscle activities of both M. brachioradialis and M. flexor carpi ulnaris observed for \( n = 10 \) adults and for all \( n = 9 \) children/adolescents. Only for the M. brachioradialis of test person C12 and for the M. flexor carpi ulnaris of test persons A2, A11 and C9 an increase of the muscle activity was observed.

Fig. 5. Muscle activities within the periodic loading measured with the new carabiner ERGOTEC normalized on the activities measured with the customary carabiner One-Touch (left: adult test persons A1 to A12; right: children/adolescents C1 to C12)
3.3. Ergonomic analysis

A more detailed video analysis was carried out for the evaluation of differences in ergonomics and user friendliness of the carabiners. Figure 7 shows typical positions of the fingers when pushing the latch of the carabiners. Due to different hand anthropometries and muscle forces differences in operation and handling of the via-ferrata carabiners, i.e. the position of the transmission of the finger forces, were observed. To compensate the lower finger forces children use the advantage of a better lever arm for all three tested carabiners, i.e. the distance of the force transmission to the hinge joint increased. But with this position of the fingers it is difficult to mount the customary carabiners in the steel cable. The design of the via-ferrata carabiner ERGOTEC allows a wider opening of the pushed latch and it is possible to mount the carabiner in the steel cable without finger contact also with the anthropometry of smaller child hands (Fig. 8).
4. Conclusion

With the new effort saving via-ferrata carabiner a reduction of muscle activity compared to two customary carabiners was observed for adults as well as for children and adolescents. However in the handling of the via-ferrata carabiners differences were observed due to different hand anthropometries and muscle forces. Only with the design of the new via-ferrata carabiner ERGOTEC it is possible to mount the carabiner in the steel cable without finger contact also with the anthropometry of smaller child hands.

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