ACCURACY OF PREDICTION OF MAXIMUM RESISTANCE AT INCREASED HOLDING TIMES BASED ON A THREE SECONDS MAXIMUM STATIC STRENGTH TEST OF THE THREE MAIN STRENGTH ELEMENTS ON RINGS

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Abstract

On rings in men's artistic gymnastics, a high degree of relative maximum strength is crucial to present up to seven strength elements in the required quality in the routine. To increase this specific strength and strength endurance the coaches often prolong the holding times of those elements by using the devices counterweight and additional weight in training. The purpose of this study was to investigate the predictability of the maximum resistance (MR) (minimal counterweight/maximum additional weight) at five and seven seconds holding times based on the MR at three seconds of the elements Iron Cross (C), Support Scale (SS) and Swallow (S) and to provide coaches with a reliable conversion table that predicts the individual training weights at different holding times. Ten male gymnasts of the Swiss National Team performed a specific static MR-Test (three, five and seven seconds holding time) of the elements C, SS and S. The results showed a significant decrease in MR as holding time increased (t-Test: $p < 0.001$). The standard error of estimate (SEE) and explained variance (R^2) revealed that the prediction of MR at five seconds (SEE 0.52 kg to 1.03 kg, R^2 0.92 to 1.00) was more accurate than at seven seconds holding time (SEE 0.95 kg to 2.08 kg, R^2 0.88 to 0.98). Based on the linear regression equations, a useful conversion table was established that predicts the MR at five and seven seconds holding time based on the three seconds MR at each of the tested elements.

Keywords: *Artistic Gymnastics, rings, strength, swallow, cross, support scale.*

INTRODUCTION

The Code of Points (CoP) of the International Gymnastics Federation (FIG) (FIG, 2013) regulates the scoring of elements and amongst others, prescribes the composition of the routines for each of the six disciplines in men's artistic gymnastics (MAG). On rings, a routine can include a maximum of seven strength elements, which have to be held in a perfect hold position, prescribed in the CoP, for at least two seconds. All angular deviations and reduction of holding time will result in deductions or non-recognition by the jury (FIG, 2013). In order to present a routine in the prescribed quality, a high level of relative maximum strength in the different hold positions is required. To increase this specific strength, it is essential that the strengthening exercises are similar, if not identical, to the holding positions of the ring elements, and that exercise intensity is optimal.

Traditionally, the hold elements are trained with help of the coaches who guide athletes' motion or partially support their body weight. The disadvantage of spotting is that the intensity of the strength training cannot be modulated optimally. On the other hand, common strengthening exercises with barbells or dumbbells, while allowing intensity to be controlled precisely, do not elicit muscle activation patterns similar to those during elements on rings (Bernasconi, Tordi, Parratte & Rouillon, 2009). Furthermore only a few preconditioning exercises seem to be strongly correlated to the holding elements on rings (Hübner & Schärer, 2015).

As specificity and progression are both fundamental principles of strength training and as the development of the specific relative maximum strength is one of the most important goals in training for the rings, there is a need for training devices that meet both demands – specificity and control of intensity. Moreover, considering the fact that coaches need to continuously adapt training stimuli to maximize progress of the athletes, they are in need of easily applicable measurement tools to regularly assess the specific maximum strength. Previously published studies have focused on the application of a specific force measurement device (Starischka & Tschiene, 1977), force plates (Gorosito, 2013; Dunlavy et al., 2007) or electromyography (Bernasconi et al., 2009; Bernasconi, Tordi, Parratte, Rouillon & Monnier, 2006). Tests using those devices must be conducted by experts and the testing procedures developed in these studies only assess the athletes' current condition. Thus, coaches cannot deduce the essential stimulus intensity needed for training.

The training devices "Counterweight" (CW) (figure 1) and "Additional Weight" (AW) (figure 2) present simple and practical means of training and testing maximum resistance (MR) in all hold positions on rings. The CW diminishes the gymnast's body weight by a pulley and activates similar muscle patterns to the ones activated without device (Bernasconi et al., 2009). The AW increases the resistance during the hold element by adding weight to a belt. Thus, it is possible that coaches can determine athletes' individual MR represented by either the minimal counterweight or maximal additional weight in each holding position during regular training sessions. As a result, the optimal specific training intensity can be deduced, which according to Mironov & Schinkar (1995) is an effective way to improve the individual level of relative maximal strength. In addition, with these devices, athletes have direct feedback regarding their training progress, which is important for their future motivation in strength training.

Coaches are constantly on the lookout for new, more effective strength training methods, which may allow athletes to include more difficult strength elements with a higher quality in their routines on the rings. A limiting factor for integrating new skills into a routine may be the specific maximal strength endurance in each holding position. Hence coaches often increase the holding times of the hold elements during the training sessions to five or even seven seconds in order to possess a higher level of MR than required during their routine. This is according to Arkaev and Suchilin (2004) crucial for presenting a routine in high quality. Until now, gymnasts needed several attempts to find the ideal counterweight or additional weight in order to hold the elements for five or seven seconds during training. To facilitate the determination of the training weights for the different holding times for the athletes and coaches, a conversion table (based on the MR at three seconds) would be of interest. In this manner, the exhaustive estimation of MR at longer holding times doesn't have to be conducted, and the risk of severe shoulder injuries due to excessive resistance can be minimized.

The aim of this study was to determine the predictability of maximum resistance (MR), in terms of counterweight or additional weight, at different holding times (five and seven seconds) based on the MR at three seconds of the hold elements Iron Cross (C), Support Scale (SS) and Swallow

(S) on rings, and to provide coaches with a reliable conversion table (CT) for predicting the training weight needed to hold an element for five and seven seconds based on individual MR for a three seconds holding time. Research question is what is the accuracy of prediction of maximum resistance at five and seven seconds holding times based on a three seconds static maximum strength test of the elements Iron Cross, Support Scale and Swallow on rings using the devices counterweight or additional weight? We hypothesized that accuracy of prediction of maximum resistance decreases with increasing holding times at the elements C, SS and S.

METHODS

To estimate MR in the hold positions of C, SS and S, two devices were used: the CW and the AW (Figures 1-6). For athletes who have not mastered the hold elements under original conditions, CW was used, whereas those who were able to execute the elements performed them either without any weight or with AW. The MR will be indicated as a negative value if CW was used and as positive value if the holding element was performed with AW.

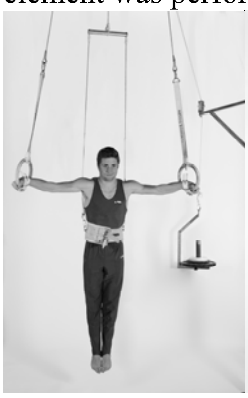

Figure 1. CW iron cross.
Figure 2. AW iron cross.

Figures 3. CW Support scale.
Figures 4. AW Support scale.

Figures 5. CW Swallow.
Figures 6. AW Swallow.

Ten top-level gymnasts from the Men's Artistic Gymnastics Swiss National Team (Age: 21.5 ± 2.5 years; Weight: 65.0 ± 5.0 kg; Height: 168.6 ± 4.5 cm) volunteered to participate in this study. All gymnasts invest more than 25 hours per week in a professional gymnastics training. Athletes were informed in advance about the test procedures, which were accepted by an ethics committee.

The tests were conducted on two separate days. On the first day, athletes performed the C; on the second day, they performed the SS and S. After an individual 20-minute warm-up, all gymnasts executed the strength elements for three, five and seven seconds in three randomized trials. Athletes had maximum three attempts per element and holding time in order to execute the element for the required time with maximal resistance. Between attempts, athletes had a twenty minutes break.

After adjusting the weight, athletes had to lower themselves into the correct position out of the support position and hold the element for the required time. All trials were captured by a video camera (Sony HDR-CX730E, Sony, Japan) positioned in front (for C) or on the side (for SS and S). Angular deviations and the time the elements were held were analyzed with Kinovea Software 0.8.15 (www.kinovea.org). Attempts were only valid if the angular deviations were within the requirements of the CoP (< 45°) (FIG, 2013). Time measurement started when a complete stop position was reached (maintaining the holding position during at least two subsequent video frames) and stopped by the time the athlete aborted the hold position or if the hold element would no longer have been recognized according the rules of the COP due to angular deviations of more than 45° (figure 7). Joint angles were estimated by marking the relevant joint centers (wrist, shoulder, hips or ankle) with the angular measurement tool of the software. This two-dimensional joint-angle video-analysis method showed high intratester reliability (Stensrud, Myklebust, Kristianslund, Bahr, Krosshaug, 2010) and concurrent validity (Norris & Olson, 2011) in medical test settings.

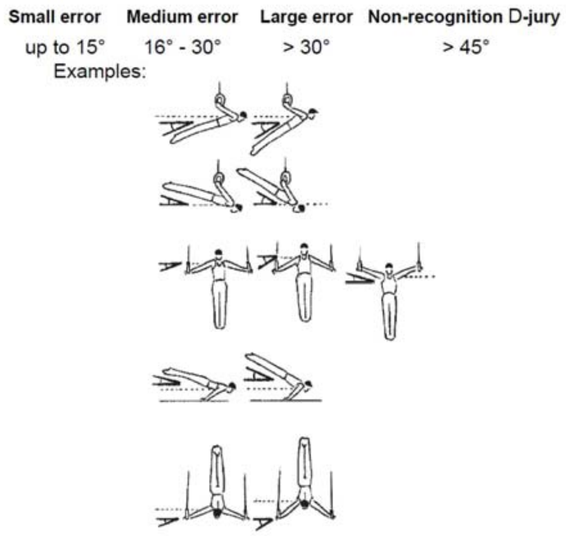

Figure 7. FIG (2013) error definition.

Mean value (M) and standard deviation (SD) of all variables were calculated. A simple linear regression equation (y = ax + b), the variance explained (R^2) (multiple regression analysis) and the standard error of estimate (SEE) were determined to describe the relationship between the MR and the different holding times for each element (C, SS, S). A t-Test was used to describe the differences between the MR at the different holding times. Using the obtained simple linear regression equations, a conversion table was calculated for the training weights at five and seven seconds holding time based on the weights at three seconds. The level of significance was set to $p < 0.05$. All statistics were performed using SPSS 22 software (SPSS, Inc., Chicago, IL).

RESULTS

Due to elbow pain resulting from a previous trauma one athlete was unable to execute the tests of C and S and felt pain holding the element SS. For this reason his results were excluded from the calculations. None of the other athletes were previously injured nor did they experience pain during the tests.

Descriptive data and achieved performances of MR at the elements C, SS and S and the effective holding times are shown in table 1.

All athletes showed the C without counterweight for the three seconds holding time. For the five and seven seconds holding times, two and four athletes, respectively, needed a counterweight in order to hold the position for the required time. The SS was hold by two athletes with additional weight. For the S, counterweights were required with the exception of one athlete for the three seconds holding time.

There were mostly minor differences between the prescribed and mean measured holding times except at the seven seconds holding time of the element S.

Mean values of the MR and the effective holding times as well as regressions and simple equation formulas for the C, SS and S are shown in Figures 8 to 10.

Table 1

Descriptive data and achieved performances of MR and the effective holding times

Athlete		1	2	3	4	5	6	7	8	9
Iron Cross	MR 3s (kg)	0.00	3.00	6.00	4.00	8.00	1.00	7.00	0.00	1.00
	MR 5s (kg)	-5.00	2.00	5.00	2.00	6.00	0.00	5.00	-3.75	0.00
	MR 7s (kg)	-10.00	0.00	2.00	0.00	5.00	-2.50	2.00	-7.50	-7.50
	Time 3s	3.12	2.32	2.48	3.80	3.92	3.00	3.52	3.52	2.96
	Time 5s	5.92	4.76	4.56	5.92	5.56	5.56	4.96	4.24	4.88
	Time 7s	8.20	6.68	6.52	7.92	6.88	7.64	7.44	7.72	7.08
Support Scale	MR 3s (kg)	-10.00	-8.75	-7.50	0.00	1.00	-10.00	1.00	-17.50	-5.00
	MR 5s (kg)	-13.75	-12.50	-10.00	-2.50	0.00	-15.00	0.00	-20.00	-6.25
	MR 7s (kg)	-15.00	-15.00	-12.50	-3.75	-3.75	-17.50	-2.50	-22.50	-7.50
	Time 3s	3.64	3.60	3.08	3.56	2.92	2.80	3.56	3.08	2.24
	Time 5s	4.52	5.44	5.40	5.64	4.60	5.12	5.60	4.80	4.28
	Time 7s	7.04	7.16	10.00	8.16	5.92	8.11	8.24	9.08	6.76
Swallow	MR 3s (kg)	-17.50	-7.50	-11.25	-7.50	-7.50	-17.50	0.00	-25.00	-12.50
	MR 5s (kg)	-20.00	-10.00	-12.50	-10.00	-8.75	-18.75	-1.25	-28.75	-15.00
	MR 7s (kg)	-22.50	-15.00	-13.75	-11.25	-10.00	-20.00	-2.50	-30.00	-20.00
	Time 3s	3.28	3.68	1.48	4.25	3.72	4.20	3.12	3.92	3.40
	Time 5s	4.64	5.48	5.56	5.72	4.88	5.92	4.00	7.44	4.92
	Time 7s	10.08	9.12	8.60	7.44	6.88	6.24	7.28	8.68	8.36

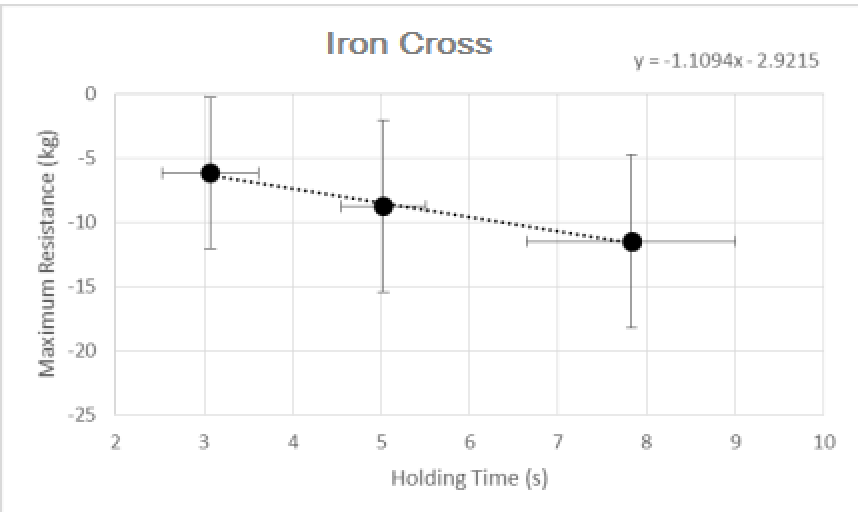

Figure 8. Mean values of the MR, the effective holding times, regressions and simple equation formulas.

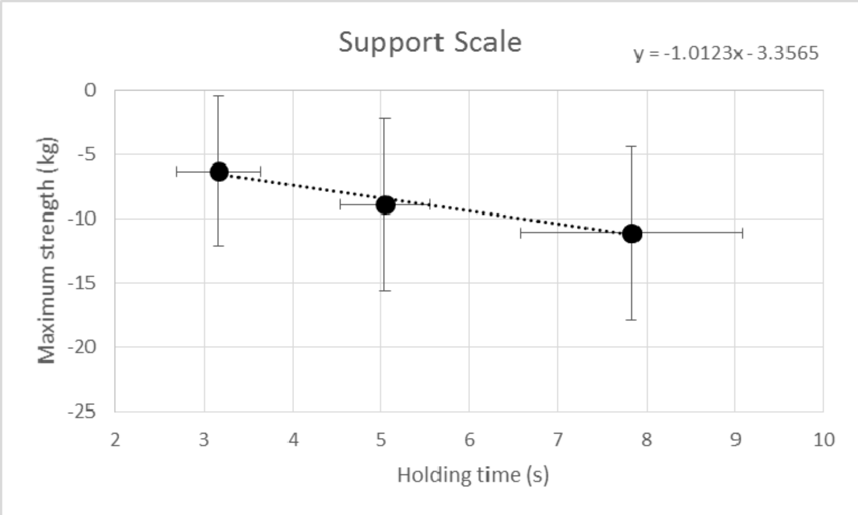

Figure 9. Mean values of the MR, the effective holding times, regressions and simple equation formulas.

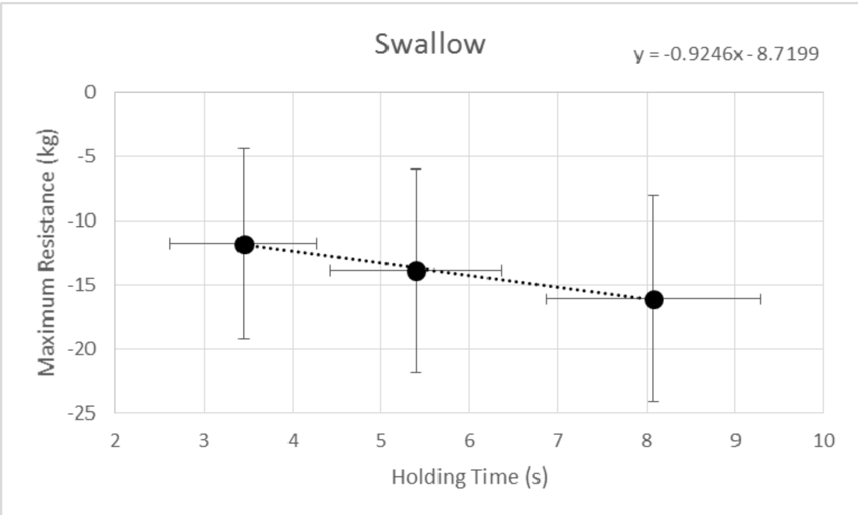

Figure 10. Mean values of the MR, the effective holding times, regressions and simple equation formulas.

Table 2
Mean values of the MR, the effective holding times, regressions and simple equation formulas.

	Iron Cross		Support Scale		Swallow	
Holding time	5s	7s	5s	7s	5s	7s
MD (%) of MR	96.3%	92.2%	96.6%	92.9%	96.5%	92.8%
(SD)	*(1.6%)*	*(3.4%)*	*(1.1%)*	*(2.5%)*	*(1.3%)*	*(2.9%)*
R^2	0.92	0.88	0.99	0.98	1	0.96
SEE (kg)	1.03	1.81	0.82	0.95	0.52	1.69

Table 3
MR for the three, five and seven seconds holding time prediction.

Iron Cross	Support Scale	Swallow

Time	3s	5s	7s	3s	5s	7s	3s	5s	7s
Maximum Resistance (kg)	5.00	3.00	0.00	5.00	2.00	0.00	5.00	3.00	2.00
	4.00	2.00	-1.25	4.00	1.00	-1.25	4.00	2.00	1.00
	3.00	1.00	-1.25	3.00	0.00	-1.25	3.00	1.00	0.00
	2.00	0.00	-2.50	2.00	0.00	-2.50	2.00	0.00	-1.25
	1.00	-1.25	-3.75	1.00	-1.25	-3.75	1.00	0.00	-2.50
	0.00	-2.50	-5.00	0.00	-2.50	-5.00	0.00	-1.25	-3.75
	-1.25	-3.75	-6.25	-1.25	-3.75	-6.25	-1.25	-2.50	-5.00
	-2.50	-5.00	-7.50	-2.50	-5.00	-7.50	-2.50	-3.75	-6.25
	-3.75	-6.25	-8.75	-3.75	-6.25	-8.75	-3.75	-5.00	-7.50
	-5.00	-7.50	-10.00	-5.00	-7.50	-10.00	-5.00	-6.25	-8.75
	-6.25	-8.75	-11.25	-6.25	-8.75	-11.25	-6.25	-7.50	-10.00
	-7.50	-10.00	-12.50	-7.50	-10.00	-12.50	-7.50	-8.75	-11.25
	-8.75	-11.25	-13.75	-8.75	-11.25	-13.75	-8.75	-10.00	-12.50
	-10.00	-12.50	-15.00	-10.00	-12.50	-15.00	-10.00	-11.25	-13.75

The means of MR for all elements decreased significantly with increasing holding time (t-Test: $p < 0.001$). The mean decline of MR based on the MR at three seconds (= 100 %) showed very similar values for all elements but indicated smaller SD at the five than the seven seconds holding time.

The very high values of the explained variance (R^2) showed stronger relationships between the measured and predicted values of MR at the five than the seven seconds holding time for all elements.

The standard error of estimate (SEE) between the calculated and measured values revealed higher accuracy at the five than at the seven seconds holding time (table 2).

Based on the previously calculated linear regression equations for the elements C, SS and S (Figures 8 to 10) and the MR of the three seconds holding time, MR for the five and seven seconds holding time were predicted, yielding the following conversion table (table 3).

DISCUSSION

In this study, the predictability of the MR, expressed as minimal counterweight or maximal additional weight, of the elements Iron Cross, Support Scale and Swallow on the rings at five and seven seconds based on the three seconds holding time MR in a specific static maximal strength test was examined.

As expected the MR decreased significantly with increasing holding times for all elements. For all elements, increasing the holding time from three to five seconds leads to a decrease in MR of 3.5 % to 3.7 %. Increasing the holding time to seven seconds reduces the MR by 7.2 % to 7.8 % compared with the three seconds holding time. These results correspond with the findings of Simkin (1959) and Kamimura & Ikuta (2001), who found a gradual decrease of maximal isometric grip strength ratios every second. The reason for this might be explained by the high intensity of maintaining these static elements (Rozand, Cattagni, Theurel, Martin & Lepers, 2015).

The results reveal a generally higher predictability of the MR at the five than the seven seconds holding time, for all elements. These findings are comparable to those of Reynolds, Gordon and Robergs (2006) and Brechue and Mayhew (2009), who found a higher predictability of the 1RM from lower repetition maximum testing than from 10 or more repetitions.

The calculations of MR at the element S showed small variance and high predictability due to the homogenous performances. Only two athletes had training experiences with this element. Moreover, all athletes except one had to use a counterweight to reach the required holding times.

The prediction of MR for the element SS shows the highest accuracy at the five and the seven seconds holding time. Especially the very low SEE at seven seconds is noteworthy. Thus, in general the discrepancies between predicted and real weight shouldn't exceed one kilogram.

The Iron cross was the only element where the deviation between measured and predicted weight at five seconds was greater than one kilogram. Six athletes (athlete 2 to 8) in this study showed the element Iron Cross in their competitive routine and they were accustomed to its intense load. They tended to use more additional weight for the five and seven seconds holding time than predicted. However the other three gymnasts with less training experience had a much higher decrease of MR with increasing holding time. One reason for this could be that the athletes are not used to the strain on the shoulder, which in turn influences stamina and leads to a higher chosen counterweight. According to Zatsiorsky & Kraemer (2006) isometric strength training might be painful if the athlete isn't able to maintain the holding position of the element (eccentric phase at the end of the holding time if the chosen intensity is too high). Furthermore these authors consider isometric strength training only as a complementary method to the usual concentric exercises, because maximum strength only increases slightly and only during the first six to eight weeks. But as isometric contractions improve the strength level particularly at the angle at which they are executed, and the training of the hold elements is necessary to develop the technical skills (muscle coordination and efficiency of muscle innervation during the static holding), the training of the static hold position is crucial for developing the required strength for elements on rings (Hesson, 1985). In accordance with the findings of Starischka (1978) and Starischka and Tschiene (1977), who observed a significant improvement of the Iron Cross-specific MR if the hold element is trained at 90 % of maximum intensity, reducing the intensity by varying the holding time might be an interesting way to vary the training stimulus (volume and intensity) while also protecting the gymnast's joints from overload or injury.

Nevertheless, the prediction of the MR at increased holding times is highly accurate and does not differ much more than the smallest possible weight increment on average. Therefore it is admissible to calculate a conversion table based on the obtained regression equations, to predict the MR at five and seven seconds holding time. If individual variation appears in training, the resistance has to be adjusted individually.

In order to get more detailed findings regarding the individualization of the rings-specific training, follow-up studies should focus on the use of surface electromyography (EMG) during holding elements. The detection of the main holding-muscles, the muscle activation patterns and the inter-individual differences between top- and lower-level gymnasts would be of interest. Subsequently, the effectiveness of any specific strength training method could be determined more precisely.

CONCLUSIONS

In summary

• The MR diminishes significantly ($p < 0.001$) for all elements with increasing holding time. Based on the MR at the three seconds holding time, the MR decreases by 3.5 – 3.7 % at five and by 7.2 – 7.8 % at seven seconds holding time.

• The prediction (R^2 and SEE) of the MR (based on the MR at three seconds) for all elements is more accurate at five (R^2: C: 0.92; SS: 0.99; S: 1.00, SEE: C: 1.03 kg; SS: 0.82 kg; S: 0.52 kg) than seven seconds (R^2: C: 0.88; SS: 0.98; S: 0.96, SEE: C: 1.81 kg; SS: 0.95 kg; S: 1.69 kg).

• With help of the linear regression equations, a useful conversion table was calculated to predict the MR at five and seven seconds holding times based on the MR at three seconds (Table 3). Subsequently, the coaches only have to estimate the MR at three seconds holding time.

• A certain individual variation between the real and predicted weight cannot be excluded, especially for the seven seconds holding time and for athletes with little or no experience with this sort of specific strength training.

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