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A COMPARISON OF MAXIMAL TORQUE LEVELS OF THE DIFFERENT PLANES OF MOVEMENT OF THE SHOULDER-GIRDLE COMPLEX FOR DIFFERENT TYPES OF SPORTS

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ABSTRACT

It is often assumed that because different sports require specific skills, the torque levels differ from sport to sport. The purpose of this study was to establish whether there were significant differences in the maximal torque levels of the different planes of movement of the shoulder-girdle complex for different types of sport. The peak torque levels obtained in this study were also compared to those obtained in similar studies done for other sports. In the absence of torque norms for the shoulde-girdle complex for the average population as well as competitive athletes, a spin-off of this study was isokinetic torque values that may act as guidelines in generating norms for the different planes of movement in different types of sport. It was found that no difference existed for all planes of movement between cricket players and the non-athletic population. These two groups, however, differed significantly from the rugby players.

Key words: Maximal torque levels; Shoulder girdle complex; Concentric peak torque.

INTRODUCTION

In the past few years in South Africa, sports medicine clinics, physical fitness centres, major hospitals and universities have established health-maintenance and injury-prevention programmes. One aspect of these programmes includes off-season, pre-season and in-season assessment of muscle strength (defined as the amount of force produced in Nm of torque) to identify functional imbalances and/or weaknesses.

There has been a glut of information on the evaluation and treatment of shoulder joint complex injuries and, in particular, the athletic shoulder (Wilk & Arrigo, 1993: 365). However, there seems to be a lack of information on the torque norms for the shoulder-girdle complex for the average population as well as for competitive athletes (Mayer *et al*., 1994: s26).

Since different types of sport require specific skills, it can be assumed that the torque levels that an athlete can tolerate may differ from sport to sport. The question arises whether there is a minimal torque level an athlete should achieve in order to participate safely in a specific sport (Gilliam *et al*., 1979: 110). At all competitive levels, there is the ever-present risk of injuries during the conditioning phase as well as the competitive phase. Wilk and Arrigo

(1993: 365) reported that especially injuries to the shoulder-girdle complex had a high incidence. Recently it has been suggested that strength imbalances may increase the risk of injury to the athlete (Chandler *et al*., 1992: 455). Muscle imbalances have been identified as either naturally occurring or training-induced. In order to be able to draw conclusions on the shoulder regarding muscle imbalances, it is necessary to compile standard values of maximum torque levels of the different planes of movement of the shoulder-girdle complex for untrained healthy subjects and different types of sport. If deviations from these standard data occur in types of sport patients or athletes, injuries or changes in strength of the shoulder, specific to the type of sport, can be demonstrated, as have already been done for the knee joint (Mayer *et al*., 1994: s19).

Only a few working groups, each using different measuring methods, have concerned themselves with determining of maximum strength in the shoulder musculature (Mayer *et al*., 1994: 519). This study is, therefore, aimed at comparing the maximal torque levels for the different planes of movement of the shoulder-girdle complex for different types of sports. In addition, this study is intended to establish if certain anthropometric variables are related to the shoulder-girdle variables.

In South Africa, especially after its re-admittance to international sport, there has been a need for sport-specific norms. There is also a need for comparisons with our international counterparts to determine how our top athletes compare with regard to maximal and relative strength.

Clinicians should exercise caution when generalizing normative values from available studies. For example, external rotation peak torque ranging from 11 to 23 Nm and 24 to 35 Nm, and internal rotation peak torque ranging from 18 to 30 Nm and 41 to 57 Nm, have been reported for non-athletic females and males respectively (Mcisc & Kramer, 1991: 40). These wide score ranges can be attributed to differences in angular velocity, test position, and profile of test subjects, suggesting that comparisons be restricted to similar test protocols. Isokinetic testing has been demonstrated to be a reliable method of testing muscular performance (Conelly Maddux *et al*., 1989: 264).

The purpose of the present study was to

- establish if there are significant differences ($p<0.05$) in the maximal concentric torque levels of the shoulder-girdle complex for abduction and adduction (60^o/sec & 180^o/sec), flexion and extension (60^o/sec & 180^o/sec) and internal and external rotation (60^o/sec & 120^o/sec) in different types of sport;
- establish the order (high to low) in the maximal torque levels of the different planes of movement of the shoulder girdle complex;
- establish the agonist/antagonist muscle ratios of the shoulder girdle complex;
- establish isokinetic torque values that may act as guidelines for norms for the different planes of movement of the shoulder girdle in top athletes.

The main research question to be addressed by this study is, therefore, whether there is a difference between the maximal torque values of the different planes of movement of the shoulder-girdle complex for different types of sport.

MATERIALS AND METHODS

Subjects

Eighty subjects participated in this study. The population of subjects consisted of the following:

- a group of non-athletic healthy university adult men (N=20).
- a group of provincial and international rugby forwards (N=20) (3 hookers, 6 props, 5 locks, 6 loose forwards).
- a group of provincial and international rugby backs (N=20) (4 scrumhalfs, 2 flyhalfs, 7 centres, 4 wings, 3 fullbacks).
- a group of provincial and international cricket players (N=20) (2 wicketkeepers, 11 bowlers, 7 batsman).

The university students were selected randomly from a volunteer population, all of whom attended the university. The provincial and international players volunteered for isokinetic testing as a part of their physical examination. None of the volunteers had a history of pathology, recent injury, or previous surgery to the tested shoulder complex.

Testing took place in season. Tests included measurement of body mass, height and maximal isokinetic concentric strength of the shoulder-girdle complex. The order of testing was the same for each subject, with muscular strength assessed last.

Testing procedure

Body mass

A calibrated secca electronic scale was used to determine the subjects' body mass. The body mass was measured without shoes and wearing only essential clothing. The body mass was measured to the nearest 0.1 kilogram.

Body length

Normal standing height was measured with the harpenden anthropometer. The subject was measured while standing with his head, back and heels against the stick. An easily adjustable sliding plate was lowered to a few centimeters above the subject's head. The subject was instructed to take a deep breath during which the sliding plate was lowered until firm contact was made with the highest point of the subject's cranium. The plate was fixed at that height and the subject was instructed to breathe out and step down. The height was read and recorded in centimetres to the nearest millimetre.

Maximal isokinetic strength testing

The tests were conducted on the Cybex 6000 isokinetic dynamometer and the upper body exercise table (UBXT). Torque scores actually represent the moment of force produced by muscle contraction for rotation around a joint, but the term "torque" is mostly used for this quantity. The manufacturers' standard protocol was used to conduct all the tests. Maximal concentric torque levels (Nm) of the shoulder-girdle complex were determined at speeds of 60^o/sec and 180^o/sec for abduction, adduction, flexion and extension, and at 60^o/sec and 120^o/sec for internal and external rotation as advised by the Cybex User's Guide (1993: A11).

Based on the side used for handwriting and throwing, the dominant shoulder was measured for all subjects in all three planes of movement (abduction/adduction, flexion/extension, and internal/external rotation). Subjects warmed up using an Upper Body Ergometer (Cybex User's Guide, 1993) for 3 minutes. The warm-up load was 300 kg/m at 60 revolutions per minute. Before the test commenced, each subject received uniform instructions regarding the isokinetic dynamometer as well as procedures that were to be followed. Three sub-maximal warm-up repetitions preceded the true test. Verbal encouragement was given during the test to ensure maximal torque output. Visual feedback was given at the end of each session to ensure consistency. The order of testing both for speed and position was determined randomly. This was done by the subject drawing lots from previously marked pieces of paper. The subjects were given at least a two-minute rest period between each group of three contractions. This has been established as the time necessary to achieve 98% recovery following repeated contractions (Walmsley & Szybbo, 1987: 218).

During shoulder abduction and adduction, the subject was seated and strapped to the UBXT. Having the contralateral arm hold on to a fixed handle during the test ensured further stability. The feet were placed on a footrest. The axis of rotation of the shoulder was centred with the dynamometer's axis of rotation. The test began in full adduction. During extension and flexion, the subjects were assessed in supine position. The knees were flexed and the feet were placed on a footrest. The contralateral arm held on to a handle to ensure stability. The test started in full flexion. Internal and external rotation were tested in the neutral position. Each test started in full external rotation.

Statistical analysis

All statistical tests were done with the STATISTICA software package for Windows from StatSoft [StatSoft].

Data analysis included computation of descriptive statistics (means, standard deviations and correlations). An analysis of variance test (ANOVA) is the usual test to determine whether the means of the shoulder-girdle variables differ significantly between sports. If, however, it is suspected that other factors (apart from the sports factor) are related to the absolute peak torque values, it would be appropriate to include these factors in the design. These factors are then controlled and in this way the power of the test is increased. If the factors are continuous variables, they are called covariates and the test is then called analysis of covariance (ANCOVA). If the ANCOVA test indicated significant differences between sports, Scheffe's test was used to test for significant differences between mean pairs.

RESULTS

Demografic (anthropometric) information

Age, body mass and body length were recorded for each subject. The means and standard deviations of the anthropometric data are represented in Table 1.

TABLE 1. **ANTHROPOMETRIC DATA OF MALE SUBJECTS**

Sport	N	Age Mean	Age SD	Height Mean	Height SD	Weight Mean	Weight SD
Non-athletes	20	21.71	2.18	178.02	9.25	76.52	15.36
Rugby forwards	20	24.31	3.53	190.21	6.74	105.85	8.34
Rugby backs	20	24.46	3.67	180.33	4.80	84.09	3.64
Cricket players	20	19.96	2.00	179.54	6.65	77.29	9.76

To determine if the anthropometric variables are related to the shoulder-girdle variables, correlations were calculated. The correlations showed no clear pattern. Significant ($p<0.05$) correlations were found between body length and weight and all the shoulder-girdle variables for the non-athletes. For all the other types of sport, only isolated significant correlations were found between the anthropometric variables and the shoulder-girdle variables. This indicates that a strong relationship does not obtain between the anthropometric variables and the peak torque values of the shoulder girdle variables. The effect of age, body weight and height on the shoulder-girdle variables, therefore, did not have to be controlled in a one-way analysis of covariance (ANCOVA) test with fixed effects. A standard ANOVA test was consequently performed to test for significant (0.05 level of significance) differences between the different sports.

ANOVA results

Abduction and adduction comparisons

The results of the ANOVA tests of the peak torque abduction and adduction absolute values for both speeds are shown in Table 2. As demonstrated in the table, the values for adduction are substantially higher than the values for abduction. This is true for both speeds. The ANOVA test found the means for the different types of sport to be significantly different for both abduction and adduction and for both speeds.

When the means are tested pair-wise, Scheffe's test showed no statistical differences between the means of the non-athletic group and the cricket players for both abduction and adduction and at both speeds. In the case of adduction at 60^o/sec, the means of the rugby forwards and backs were also not significantly different. The means of all the other pairs were significantly different.

Flexion and extension comparisons

Table 2 displays the statistical results of the peak torque values for flexion and extension at both speeds. The corresponding values in this table are all lower than the values for adduction. For the subjects, the mean values differed significantly between the different type of sport according to the one-way ANOVA test.

Scheffe's tests indicated no significant differences between non-athletic subjects and cricket players for both flexion and extension and at both speeds. No significant differences between the means of rugby backs and forwards were found in the case of flexion at 60^o/sec and 180^o/sec and extension at 180^o/sec. The means of all the other pairs were significantly different.

TABLE 2. **ANOVA OF PEAK TORQUE VALUES FOR DIFFERENT PLANES OF MOVEMENT AND AT DIFFERENT SPEEDS**

N=20 in all cases. (* Marked differences are significant at p<0.05)

Plane of Movement	Speed (°/sec)	Sport	Mean	SD	F	p	A	B	C	D
Abduction	60	Non-Athletes (A)	067.1	16.1	58.01	0.00*	-			
		Rugby Forwards (B)	119.0	18.4			0.00*	-		
		Rugby Backs (C)	098.6	09.4			0.00*	0.00*	-	
		Cricket Players (D)	067.8	14.0			0.99	0.00*	0.00*	-
	180	Non-Athletes (A)	059.8	17.9	50.54	0.00*	-			
		Rugby Forwards (B)	110.7	17.4			0.00*	-		
		Rugby Backs (C)	093.2	12.1			0.00*	0.01*	-	
		Cricket Players (D)	063.8	12.9			0.88	0.00*	0.00*	-
Adduction	60	Non-Athletes (A)	125.7	24.7	20.29	0.00*	-			
		Rugby Forwards (B)	174.9	24.9			0.00*	-		
		Rugby Backs (C)	161.3	20.7			0.00*	0.41	-	
		Cricket Players (D)	125.0	29.5			0.99	0.00*	0.00*	-
	180	Non-Athletes (A)	120.7	31.7	27.87	0.00	-			
		Rugby Forwards (B)	186.6	30.1			0.00*	-		
		Rugby Backs (C)	158.4	20.5			0.00*	0.01*	-	
		Cricket Players (D)	127.0	18.2			0.90	0.00*	0.00*	-
Flexion	60	Non-Athletes (A)	066.3	20.1	30.70	0.00*	-			
		Rugby Forwards (B)	093.5	10.9			0.00*	-		
		Rugby Backs (C)	089.0	08.1			0.00*	0.74	-	
		Cricket Players (D)	062.6	07.2			0.83	0.00*	0.00*	-
	180	Non-Athletes (A)	035.7	17.3	37.76	0.00*	-			
		Rugby Forwards (B)	081.7	09.4			0.00*	-		
		Rugby Backs (C)	078.6	07.8			0.00*	0.86	-	
		Cricket Players (D)	053.6	07.2			0.99	0.00*	0.00*	-
Extension	60	Non-Athletes (A)	092.5	22.6	38.36	0.00*	-			
		Rugby Forwards (B)	132.4	16.9			0.00*	-		
		Rugby Backs (C)	115.7	07.1			0.00*	0.01*	-	
		Cricket Players (D)	084.6	12.2			0.47	0.00*	0.00*	-
	180	Non-Athletes (A)	077.7	19.6	31.41	0.00*	-			
		Rugby Forwards (B)	112.1	17.2			0.00*	-		
		Rugby Backs (C)	103.5	08.8			0.00*	0.37	-	
		Cricket Players (D)	072.8	13.5			0.79	0.00*	0.00*	-
External Rotation	60	Non-Athletes (A)	29.8	08.5	25.32	0.00*	-			
		Rugby Forwards (B)	44.4	06.0			0.00*	-		
		Rugby Backs (C)	42.7	06.8			0.00*	0.91	-	
		Cricket Players (D)	29.1	07.6			0.99	0.00*	0.00*	-
	120	Non-Athletes (A)	28.1	06.1	32.65	0.00*	-			
		Rugby Forwards (B)	42.2	05.8			0.00*	-		
		Rugby Backs (C)	37.2	06.5			0.00*	0.91		
		Cricket Players (D)	25.9	05.6			0.99	0.00*	0.00*	-

Table 2 continued

Plane of Movement	Speed (°/sec)	Sport	Mean	SD	F	p	A	B	C	D
Internal Rotation	60	Non-Athletes (A)	52.4	15.8	13.97	0.00*	-			
		Rugby Forwards (B)	80.3	10.3			0.00*	-		
		Rugby Backs (C)	66.5	07.8			0.00*	0.00*	-	
		Cricket Players (D)	50.4	08.4			0.95	0.00*	0.00*	-
	120	Non-Athletes (A)	47.1	13.9	38.36	0.00	-			
		Rugby Forwards (B)	75.1	10.6			0.00*	-		
		Rugby Backs (C)	60.6	06.7			0.00*	0.00*	-	
		Cricket Players (D)	45.5	06.9			0.97	0.00*	0.00*	-
Abduction/-Adduction	60	Non-Athletes (A)	0.53	0.07	17.78	0.00*	-			
		Rugby Forwards (B)	0.68	0.09			0.00*	-		
		Rugby Backs (C)	0.61	0.05			0.02*	0.06	-	
		Cricket Players (D)	0.56	0.10			0.86	0.00*	0.13	-
	180	Non-Athletes (A)	0.52	0.18	3.88	0.01*	-			
		Rugby Forwards (B)	0.60	0.08			0.19	-		
		Rugby Backs (C)	0.59	0.08			0.24	0.99	-	
		Cricket Players (D)	0.50	0.08			0.97	0.07	0.10	-
Flexion/-Extension	60	Non-Athletes (A)	0.71	0.09	1.83	0.15				
		Rugby Forwards (B)	0.72	0.11						
		Rugby Backs (C)	0.77	0.05						
		Cricket Players (D)	0.75	0.10						
	180	Non-Athletes (A)	0.68	0.08	3.33	0.08				
		Rugby Forwards (B)	0.74	0.14						
		Rugby Backs (C)	0.76	0.07						
		Cricket Players (D)	0.75	0.12						
External/Internal Rotation	60	Non-Athletes (A)	0.58	0.11	3.52	0.02*	-			
		Rugby Forwards (B)	0.56	0.06			0.92	-		
		Rugby Backs (C)	0.64	0.06			0.15	0.03*	-	
		Cricket Players (D)	0.58	0.11			0.99	0.87	0.17	-
	120	Non-Athletes (A)	0.61	0.10	1.83	0.14				
		Rugby Forwards (B	0.57	0.07						
		Rugby Backs (C)	0.61	0.07						
		Cricket Players (D)	0.57	0.09						

External and internal rotation comparisons

In the case of external and internal rotation, the peak torque values for the subjects at speeds of 60°/sec and 120°/sec are shown in Table 2. The corresponding values are much lower than those for adduction. The ANOVA test indicates that the means of the different types of sport differ significantly at both speeds.

For pair-wise means, those between non-athletic and cricket players were not significant for both internal and external rotation and at both speeds. The means of the rugby forwards and backs were also not significantly different for external rotation at 60°/sec and 120°/sec. The means of all the other pairs were significantly different.

Agonist/antagonist muscle ratio comparisons

Table 2 shows the peak torque agonist/antagonist muscle ratios for the subjects. Significant differences between the means of the different types of sport were found for abduction/adduction ratio at 60°/sec and 180°/sec and external/internal rotation at 60°/sec. No significant differences between the means of the different sports were found for the other ratios.

For the ratios of the subjects that differed significantly between the different types of sport, Scheffe's test was performed. The results are shown in Table 2. For the abduction/adduction ratio at 60°/sec, no differences were found between non-athletes and cricket players, rugby forwards and backs, and rugby backs and cricket players. All the other means were significantly different. For the abduction/adduction ratio at 180°/sec, none of the mean pairs between the different types of sport were significant. For by different external/internal rotation at 60°/sec, only the means for rugby forwards and backs differed significantly.

DISCUSSION

The absolute peak torque values (all planes of movement) were lower at higher speeds of movement. This is in accordance with other studies (McMaster *et al*., 1992: 324; Mayer *et al*., 1994: 519; Mikesky *et al*., 1995: 640). It is not suprising that more of the significant differences in muscle strength were observed at slow contractile speeds. The force-velocity relationship of skeletal muscle provides a possible mechanistic explanation for this finding. At slow speeds of contraction, skeletal muscle is capable of generating large force, whereas at higher contractile velocities approaching maximal shortening velocity, skeletal muscle generates very little tension. Consequently, differences in muscle strength between the muscle groups would be most noticeable at slow contractile velocities and minimal at the highest speeds of contraction (McMaster *et al*., 1992: 326). Thus, the data generated here suggest, although not conclusively, that the torque ratio shifts observed are influenced by speed of execution. More statistically significant differences were observed at slow than high speed. The values obtained in this study are, however, substantially higher than the values obtained in other studies. These differences may be attributed to the differences between types of sport as found in this study. However, these may also be attributed to differences in testing position and equipment rather than the sample of subjects. To make the comparisons meaningful, it is emphasised that only the values of the same type of sport obtained with the same isokinetic dynamometer should be compared with one another. Significant differences have been demonstrated in measures between various isokinetic dynamometers (Wilk *et al*., 1993: 65).

Caution should be exercised when using our reported absolute measures for strength assessment unless one is using a Cybex 6000 isokinetic dynamometer and a similar testing position.

It was found in other studies that extension can be considered the strongest and external rotation the weakest movement in the shoulder joint (Mayer *et al*., 1994: 23) .The results in this study indicate that adduction must be considered the strongest and external rotation the weakest movement in the shoulder joint. Ivey et al.,(1985: 384) performed a study on concentric isokinetic strength measurements (60^{o}/sec, 180^{o}/sec) in the shoulder musculature of 13 women and 18 men, and found adduction to be the strongest movement, followed by extension, abduction and internal rotation. In this study, the order, from strongest to the weakest movement, was adduction, extension, abduction, flexion, internal rotation and external rotation. This is remarkably identical to what was found by Ivey et al., (1985: 384).

Data for competitive swimmers (McMaster *et al*., 1992: 324) compared well to those for the non-athletic group of this study tested at 180^{0}/sec: abduction 56,7 Nm versus 59,8 Nm, adduction 125 Nm versus 120,7 Nm. Different high strength levels are explained by the size of the muscle mass involved, the muscle cross-section, composition of the muscle fibers and the maximum activation capacity (McArdle *et al*., 1996).

One of the goals of this study was to determine agonist/antagonist muscle ratios of the dominant shoulder (see Table 2). Regarding these ratios, several authors (Ivey *et al*., 1985: 384; Alderink & Kuck, 1986: 163; Cook *et al*., 1987: 451; Hinton, 1988: 274; Wilk *et al*., 1993: 62) have reported results. Ivey et al., (1985: 384) tested college non-athletes, while the other authors examined baseball pitchers.

Isokinetic evaluation of shoulder abduction and adduction has yielded varying results. Ivey et al., (1985: 384-386) found shoulder adduction muscles to be twice as strong as the abductors, whereas Alderink and Kuck (1986: 163) reported the abductors to be approximately 50% as strong as the adductors. Our results indicated an abduction/adduction ratio of between 50% and 60% at 180^{0} and 53% and 68% at 60^{0} /sec. These differences can be attributed to differences in test position, use of apparatus, angular velocity and the profile of test subjects, suggesting that comparisons be restricted to similar test protocols.

Our results indicated flexion/extension ratios from 71% to 75% measured at 60^{0}/sec, and 68% to 75% at 180^{0}/sec. These results are in agreement with Cook *et al*. (1987: 460) who reported ratios of 74% and 90% for male baseball pitchers and age-matched non-pitchers tested at 180^{0}/sec.

Ivey et al., (1985: 386) and Alderink and Kuck (1986: 163) found external rotator muscle strength to be approximately 66% of that exhibited by the internal rotators. Cook *et al.* (1987: 460) and Hinton (1988: 274) reported higher external to internal rotator muscle ratios of 70% and 75% respectively. The results of Wilk *et al*., (1993) indicated an external/internal rotator muscle ratio of 65% at 180^{0}/sec. Our results indicated an external/internal rotator muscle ratio (at 120^{0}/sec) of 61% for the non-athletic group and rugby backs, and 57% for the rugby forwards and cricket players. These results were lower than those obtained by other investigators. There are many possible reasons for these differences. In the Hinton (1988: 274) study, the subjects tested were high school pitchers. Alderink and Kuck (1986: 163) tested college pitchers at speeds of 90^0, 120^0, 210^0 and 300^0/sec. In addition, the dampening was set at 2 instead of the manufacturer suggested setting of 3. Cook *et al*. (1987: 451) tested college pitchers at 180^0 and 300^0/sec; however, the test position was not described in the article. All previous investigators reviewed (Alderink & Kuck, 1986: 163; Cook *et al*., 1987: 451; Hinton, 1988: 274) performed testing on a Cybex dynamometer, except Wilk *et al*. (1993: 61) who gathered data using a Biodex isokinetic testing system.

No statistical differences were found between the absolute mean torque values of the non-athletic group and those of the cricket players. This was true for all planes of movement and at all velocities. The reason for this is difficult to explain. The bio-mechanical requirements of cricket may account for this finding. Cricket requires synchronized movements of several body parts aside from the upper extremity, including the feet, pelvis and trunk (Moynes *et al*., 1986: 1905). As a result, cricket players may be characterized by a high degree of skill rather than strength differences in isolated joint movements. Significant differences were obtained between these two groups and rugby forwards and backs. Different high strength levels are explained by the size of the muscle mass involved and the muscle cross section (McArdle *et al*., 1996: 315.

It must be noted that assessment of concentric strength reveals only part of the muscle function. Eccentric contractions are also an integral part of sports performance (Mikesky *et al*., 1995: 642). Research describing upper extremity bilateral peak torque relationships proved to be inconsistent (Perrin *et al*., 1987; Mikesky *et al*., 1995: 641-642; McArdle *et al*., 1996: 434). Normative data should be collected especially for athletes participating in sports in which selected bilateral muscle groups are used in an asymmetrical manner.

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