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Effects of Plyometric Training on Rock'n'Roll Performance

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Abstract

Objectives: The aim of the study was to analyse if plyometric training increases the sport specific performance in rock'n'roll dancers. **Design:** Fifteen semi-professional rock'n'roll dancers participated in a plyometric training study. Pre- and posttests were conducted to document alterations of sport specific performance, reactive strength as well as maximal isokinetic torque. **Method:** The participants (n=15) accomplished two training sessions weekly for a training period of 6 weeks. The training program consisted of different of jumps. Pre- and posttests included a rock'n'roll specific performance test examining the maximal number of kicks within 30 s. Moreover, jumping height and ground contact time (GCT) during drop jump were determined to calculate reactive strength (RSI). Maximal dynamic torque and work were determined during maximal isokinetic contractions of the plantar flexors. **Results:** The number of kicks increased from 46.5 ± 2.6 to 49.4 ± 2.7 ($p=0.00$, $d_Z=1.83$).The RSI increased significantly from 2.57 ± 0.29 to 2.72 ± 0.44 ($p=0.05$, $d_Z=0.55$). The gains of RSI are based on increases in jumping height (pretest: 24.6 ± 4.0 cm, posttest 26.5 ± 4.7 cm, $p=0.01$, $d_Z=0.71$), whereas the GCT remained unaltered ($p=0.53$). The work during maximal isokinetic plantar flexions increased significantly in both legs (jumping leg: $p = 0.04$, $d_Z=0.58$; kicking leg: $p=0.05$, $d_Z=0.55$). **Conclusions:** Plyometric training increases the kicking frequency during rock'n'roll dance. This might be attributed to the observed increase in reactive strength. Training induced changes in muscle activity or structure were discussed. It is suggested to implement plyometric training into the training program of rock'n'roll dancers.

Keywords: Rock'n'roll, plyometric training, reactive strength, plantar flexors

1. Introduction

Physical abilities as strength and power contribute to the complex performance in many sports (Baechle & Earle, 2008). The significance of their contribution depends on the performance system of the competition (Matveev, 1981). The strength efforts in high performance rock'n'roll dancing are mainly short ground contacts during hopping and jumps. A main performance criterion is the dancing velocity regarding to the number of kicks per minute. High performance athletes have to perform kicking frequencies of more than 100 kicks per minute (Kirch, 1995; WRRC, 2012). As the frequency of kicks is equal to the frequency of hops, rock'n'roll dancers perform hops at a frequency of more than 100 per minute. The frequency of kicks or rather hops per minute depends on the reactive strength of the athletes. Reactive strength is the ability to reverse eccentric into concentric muscle actions (Gamble, 2010; Young & Farrow, 2006). Zemkova et al. (2001; 2005) showed that reactive strength and explosive power is higher in rock'n'roll dancers compared to other populations.

The aim of plyometric training is to maximize the reactive strength and power. Reactive strength can be measured using the reactive strength index (RSI). The RSI is the ratio between jumping height and time of touch down (GCT) within a stretch-shortening-cycle (for example during a drop jump). The index can be maximized by increasing jumping height while the GCT remained unaltered or by reducing the GCT while the jumping height is constant. In both cases the force during the ground contact needs to be increased. In literature it is reported that plyometric exercises are effective to develop reactive strength (Lloyd, Oliver, Hughes, & Williams, 2012) and power (Bobbert, 1990; Bobbert, Huijing, & van Ingen Schenau, 1987a, 1987b; Malisoux, Francaux, Nielens, & Theisen, 2006). Plyometric exercise is defined as a quick powerful movement that involves the stretch-shortening cycle (Baechle & Earle, 2008; Komi, 1984, 2003). It was shown that plyometric training increases the jump performance (Markovic, 2007; Matavulj, Kukolj, Ugarkovic, Tihanyi, & Jaric, 2001), RSI as well as sprint abilities (Ronnestad, Kvamme, Sunde, & Raastad, 2008). Increasing the RSI may increase the number of hops in a given time and may lead to increase the number of kicks in rock’n’roll. So far, it is unknown if plyometric training has a benefit effect on number of kicks in rock’n’roll. The aim of the study is to increase the number of kicks in young athletes by a sport specific plyometric training in rock’n’roll. It is hypothesised that plyometric training increases the RSI and the number of kicks in rock’n’roll.

2. Methods

Fifteen semi-professional rock’n’roll dancers (sex: 3 male, 12 female, age: 17.1 ± 3.0 year, weight: 58.8 ± 7.4 kg, height: 167 ± 5 cm, BMI: 17.8 ± 1.9 kg/m^2) participated in the study. All athletes trained at least three times per week. All participants that suffered on a leg injury in the past six months before the study started were excluded from the study. The participants were informed about the aims and risks of the study and gave their written consent before the study started. The study was approved by the local ethical committee of the university hospital of Dresden and conducted in accordance with the latest declaration of Helsinki.

Participants were examined before and after the plyometric training intervention regarding to reactive strength, maximum strength and a sport specific performance test. The training was conducted two times per week with at least one day rest between the training sessions. The training intervention lasted for 6 weeks and was integrated into regular dance training (Brown, Wells, Schade, Smith, & P.C., 2007). All participants completed the training phase.

Each training session started with a general warm-up containing running with moderate intensity followed by dynamic stretching of the leg muscles. Subsequently simple jumping exercises with moderate intensities were performed.

The training program started with 6 repetitions of jumping exercises. Three sets were performed. There was a 3 min rest between the sets. The participants were motivated to perform the jumping exercises with maximal power. According to the recommendations of the American College of Sports Medicine the volume was increased progressively from 42 jumps in the first week to 81 jumps in the last week (Ratamess et al., 2009). Moreover, different jumping exercises as squat jumps, tuck jumps, hurdle jumps and lateral jumps were chosen (Bosco, 1999). Hence, the kind of jumping exercise was also increased progressively in order to the intensity. Therefore, participants started with squat jumps at the beginning and performed multiple hurdle jumps with maximal explosive power in the last week. The overall design of the training program is shown in table 1.

Table 1. Training program performed by rock’n’roll dancers

Week	Repetition	Sets		Jumps total
1	6	3	Squat Jumps	42
	8	3	Lateral Jumps	
2	8	3	Squat Jumps	54
	10	3	Lateral Jumps	
3	10	3	Squat Jumps	66
	12	3	Lateral Jumps	
4	8	3	Tuck Jumps	51
	3x3	3	Hurdle Jumps	
5	10	3	Tuck Jumps	66
	4x3	3	Hurdle Jumps	
6	12	3	Tuck Jumps	81
	5x3	3	Hurdle Jumps	

2.1 Pretest / Posttest

All participants were tested before and after the end of the training intervention. After a standardized warm-up different functional tests were performed.

To assess the effect of training on dancing performance a rock’n’roll specific performance test was conducted. This sport specific motor test is a main criterion for rock’n’roll dancers and closely related to the dance performance (Kirch, 1995). The aim of the test was to complete as many as possible rock'n'roll kicks within 30 seconds. Participants executed the test two times with 5 min rest between the trials. The mean number of kicks of the two trials was used for further analyses.

Maximal dynamic torque (MVDC) during plantar flexion was determined using an isokinetic diagnostic system (ISOMED2000, D&R Ferstl GmbH, Hemau, Germany) (Stutzig & Siebert, 2015). Participants lie supine in the ISOMED2000 with one foot attached to a pedal. The hip and knee angle were completely straight and fixed with straps. The range of motion of the ankle amounted 55°. The dynamic plantar flexion was carried out at an angular velocity of 240 °/s. One set consisting of seven repetitions was conducted. The maximum torque and work were calculated for each repetition. For further analyses the data of the third until the seventh repetition were averaged.

The reactive strength (Young & Farrow, 2006) within a stretch-shortening cycle (Komi, 2000) was assessed using drop jump exercises (Fleck & Kraemer, 2004). Participants stood on a box (height: 30 cm) until jump off (Flanagan, Ebben, & Jensen, 2008). They were asked to touch down and jump off as fast as possible and hence, to jump as high as possible (Taube, Leukel, Lauber, & Gollhofer, 2011). The GCT and the flight time (t_{flight}) were assessed using a force plate (Kistler© Typ 9281EA). The data were recorded by a sample rate of 1000Hz and stored on a computer. The jumping height (H) was calculated based on the flight time:

$$H = \frac{1}{8} * g * t_{flight}^2$$

where g is the gravitational acceleration and t_{flight} is the flight time. Furthermore, a reactive strength index (RSI) was calculated as follows (Abramov, Kuporosov, & Matwejew, 1980; Bruhn, Kullmann, & Gollhofer, 2004; Flanagan et al., 2008):

$$RSI = \frac{H}{t_{gc}}$$

where t_{gc} is the ground contact time. Five single drop jumps were conducted with 30 s rest between the trials. The data of the jump with the best RSI was used for further analyses.

2.2 Statistics

The data are presented as mean and standard deviation. Moreover, data were proved for normal distribution using the Shapiro-Wilk test. A student t-test was used to detect differences between pre and posttests. The effect size (d_Z) was calculated as mean of the differences divided by the standard deviation of the differences (Cohen, 1988). The significant level was set at p=0.05.

3. Results

The number of kicks increased significantly from 46.5 ± 2.6 kicks to 49.4 ± 2.7 ($p=0.00$, $d_Z=1.83$) kicks due to the specific power training (fig. 1).

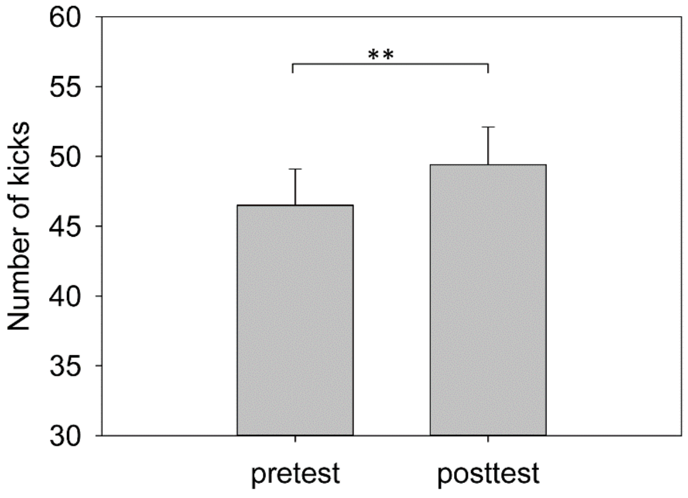

Figure 1. Mean and standard deviation of the number of kicks during the rock'n'roll specific performance test. The left bar shows the results of the test before the training intervention (pretest) and the right bar after the training intervention (posttest). ** Significant between pretest and posttest at p<0.01.

The peak torque during MVDC of the jumping leg increased significantly ($p = 0.02$, $d_Z = 0.65$) from 41.3 ± 10.9 Nm to 49.9 ± 8.1 Nm. However, the peak torque of the kicking leg did not increase significantly ($p = 0.10$) (fig.2).

The work during the MVDC increased in both jumping leg ($p = 0.04$, $d_Z = 0.58$, pre: 27.1 ± 7.4, post: 31.2 ± 5.1) and kicking leg ($p = 0.05$, $d_Z = 0.55$ pre: 28.3 ± 8.7, post: 32.5 ± 6.6) (fig.3).

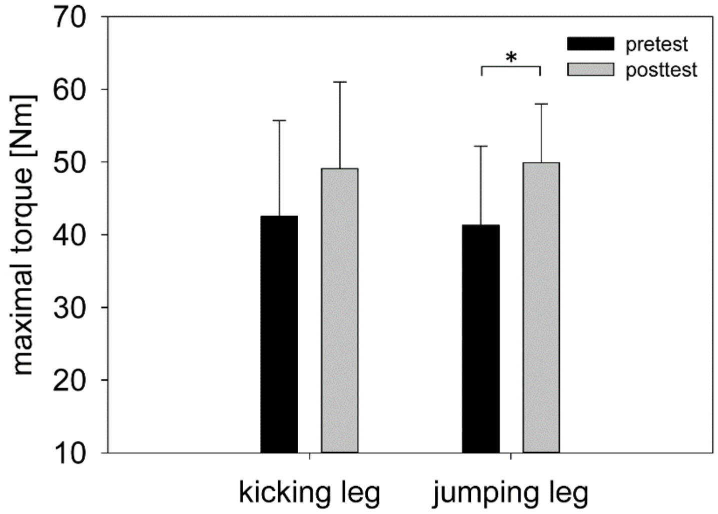

Figure 2. Mean and standard deviation of the maximal torque during the isokinetic plantar flexions of the kicking leg and jumping leg. The black and the grey bars show the results of the test before (pretest) and after (posttest) the training intervention, respectively. * Significant between pretest and posttest at $p<0.05$.

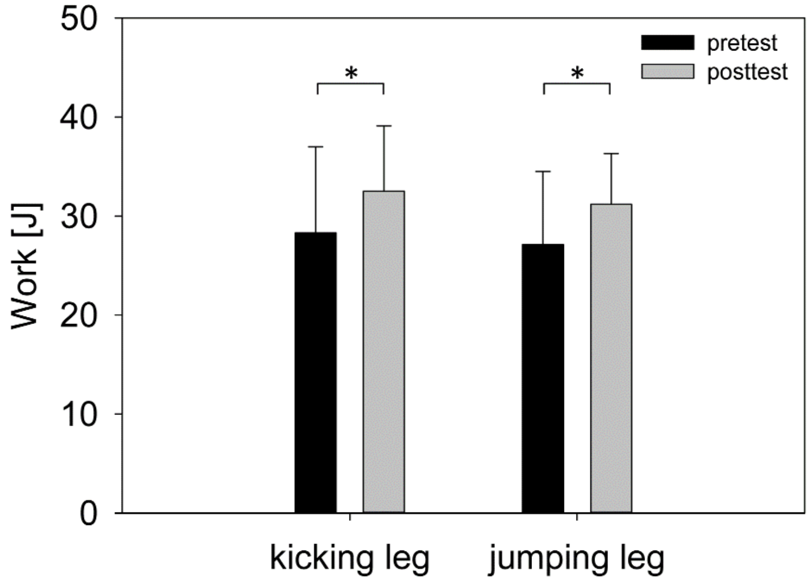

Figure 3. Mean and standard deviation of physical work during the isokinetic plantar flexions of the kicking leg and jumping leg. The black and the grey bars show the results of the test before (pretest) and after (posttest) the training intervention, respectively. * Significant between pretest and posttest at $p<0.05$.

The GCT during drop jump remained unaltered ($p=0.53$, $d_Z=0.17$) throughout the training intervention. The jumping height increased significantly ($p=0.01$, $d_Z=0.71$) from 24.6 ± 4.0 cm to 26.5 ± 4.7 cm. Moreover, the RSI increased significantly ($p=0.05$, $d_Z=0.55$) from 2.57 ± 0.29 to 2.72 ± 0.44, too (tab.2).

Table 2. Mean, standard deviation (SD) and level of significance (p) of the Drop Jump during pretest and posttest

Test	Parameter	Pretest	Posttest	p
Drop Jump	Ground contact time [s]	0.173 ± 0.015	0.170 ± 0.018	0.53
	Jumping height [cm]	24.6 ± 4.0	26.5 ± 4.7	0.01
	Reactive strength index	2.57 ± 0.29	2.72 ± 0.44	0.05

4. Discussion

This study demonstrates, that a plyometric training improves the sport specific performance of rock'n'roll dancers, e.g. by increasing the number of kicks. The athletes increased their speed from 46.5 to 49.4 kick (in 30 sec). The number of kicks corresponds to an increase of kicking frequency from 93 to 98.8 kicks per minute. According to the international rules of rock'n'roll (WRRC, 2012) the speed of music amounts 50-52 bars per minute for international tournaments. One basic step contains three kicks and lasts 1.5 bars. At a music speed of 51 bars per minute 34 basic steps need to be performed. That means high performance athletes perform a kicking frequency of 102 kicks per minute.

One possible reason for the increased number of kicks may be the observed improvement in the reactive strength index (RSI). This was reported in other plyometric studies too (Lloyd et al., 2012; Markovic, Jukic, Milanovic, & Metikos, 2007). RSI depends on GCT and jumping height (Abramov et al., 1980; Flanagan et al., 2008; Markovic, 2007). Markovic et al. (2007) conducted a plyometric training program 3 times weekly for 10 weeks. Before and after the training intervention the participants (n=30) performed maximal drop jumps. In our study the RSI increased, too. However, in the study of Markovic et al. (2007) the GCT decreased while the jumping height remained unaltered. We observed gains in jumping height and unaltered GCT. The discrepancies might be explained by the different populations participating in the two studies. In our study semi- professional dancers which were experienced in jumping were examined while Markovic et al. (2007) analyzed physical educational students who had no specific jump experience. On the other hand Kyrolainen et al. (2005) accomplished a training program for 10 weeks with recreational man. According to our and other studies (Kubo et al., 2007) they observed gains in jumping height while the GCT remained unaltered. Further, another training study with intermediate or advanced ballet or modern dancers (Brown et al., 2007) found an increase in standing vertical jumping height of 8.3% after 6 weeks of plyometric training.

An increase in jumping height is based on an increase in force impact equaling the impulse (momentum). As the observed GCT of the drop jump is constant, the increase in the impulse is attributable to an increase in the mean force. This is in accordance with increased forces measured during maximal voluntary plantar flexions. In these measurements the increased work (Fig. 3) results from an increased force, too, as the angular velocity as well as the angular range of motion were given by the isokinetic diagnostic system during the plantar flexions. Furthermore, the peak torque was increased significantly for the jumping leg and tends to increase for the kicking leg (Fig. 2). An increase in maximum force (isometric and dynamic) after plyometric training was reported by a series of studies (Kubo et al., 2007; Wilkerson et al., 2004), too. The increases of maximal force can be induced either by an increase of neuromuscular activation or changes in the muscle properties (Duchateau & Baudry, 2011).

It is documented that a time course exist between adaptations of neural and muscle factors (Sale, 1988). In early stages of strength training the neuromuscular performance increase followed by gains in the cross sectional area (Moritani & deVries, 1979).

Increased muscle activity after plyometric training was found using surface electromyography (Gollhofer & Kyrolainen, 1991; Toumi, Best, Martin, F'Guyer, & Poumarat, 2004). Kyrolainen et al. (2005) conducted a plyometric training over 15 weeks with 2 training sessions weekly. They found increased muscle activity in the plantar flexors accompanied by increased MVC force after 10 weeks of training. The changes of muscle activity of the gastrocnemius muscle and MVC force correlated well ($r=0.77$, $p<0.01$). Unfortunately, with the used methods it is not possible to distinguish if the gain in muscle activity is based on increased motor unit recruitment or increased firing rate (Duchateau & Baudry, 2011). The muscle activity can be modulated on supraspinal and spinal level. In this context increased spinal reflex activity was found after plyometric training (Voigt, Chelli, & Frigo, 1998). It was assumed that the increased muscle activity during a stretch-shortening cycle (as in drop jump) after plyometric training is based on changes in the spinal reflex activity (Voigt et al., 1998). It is not reported in literature if supraspinal adaptations occur due to plyometric training.

Moreover, improved neuromuscular performance may also caused by enhanced muscle coordination. Kyrolainen et al. (1998) observed decreased antagonistic activity during plyometric training of the upper limb muscles in untrained women. In our study jumping experienced dancers were trained. So we do not believe that improved muscle coordination is the main source of the increased jumping height and force gains. However, Kubo et al. (2007) compared weight training and plyometric training with regard to muscle activation and jump performance during drop jump. They found increased muscle activation in both training groups but the jumping height increased in the plyometric group only. Kubo et al. (2007) concluded that the improvements in jumping height are attributed to changes in the mechanical properties of the muscle-tendon complex, rather than muscle activation strategies.

First muscle strength may increase due to hypertrophy, namely the increase in the cross sectional area of individual muscle fibers. This was reported by (Andersen & Aagaard, 2000; Hortobagyi et al., 1996; LaStayo, Pierotti, Pifer, Hoppeler, & Lindstedt, 2000; Malisoux et al., 2006). However, there are some studies concluding that plyometric training does not lead to higher isometric strength or muscle hypertrophy (Hakkinen et al., 1990; Prilutsky, 2005).

Changes in muscle fiber type ratio, which could further influence muscle force (Bottinelli, Schiaffino, & Reggiani, 1991; Malisoux, Francaux, & Theisen, 2007), may have little influence, as Kyrolainen et al. (2005) found no changes in the muscle fibertype distribution after a 15 week plyometric training intervention.

In general plyometric training results in an increase in muscle-tendon stiffness (Benn et al., 1998; Lindstedt, LaStayo, & Reich, 2001; Lindstedt, Reich, Keim, & LaStayo, 2002; Pousson, Van Hoecke, & Goubel, 1990; Reich, Lindstedt, LaStayo, & Pierotti, 2000). This may be attributed to an increase of tendon stiffness, muscle stiffness, or both.

Results regarding tendon stiffness after eccentric or plyometric training are ambiguous. In humans, tendon stiffness was reported to increase after training, whether it was eccentric training (Buchanan , Almdale, Lewis, & Rymer, 1986; Duclay, Robbe, Pousson, & Martin, 2009), endurance training (Buchanan & Marsh, 2001) or strength training (Kubo, Kanehisa, Kawakami, & Fukunaga, 2001). This increase may enhance the performance during stretch-shortening cycles by favoring the release of potential energy (Bosco, Komi, & Ito, 1981; Duchateau & Baudry, 2011). However, Kubo et al. (2007) found no change in tendon stiffness but in joint stiffness after plyometric training. Thus, they suggested that greatest adaptations in muscle-tendon stiffness may be located in the muscle.

Performing an 8 week eccentric training program with rats it could be demonstrated, that the stiffness of the muscle increased by 40% significantly (Reich et al., 2000), whereas muscle mass and isometric muscle force remained unchanged. The authors concluded that the 8 week training period is sufficient to induce structural adaptations in the muscle. They suggest that the increase in active muscle stiffness may be attributed to changes in the molecular spring titin. Rode et al. (2009) suggested a physiologically motivated muscle model which explains enhanced muscle stiffness by activation dependent titin-actin interaction. The giant protein titin is a structural part of myosin with a free part acting as a molecular spring connecting myosin to the Z-disc near the actin filament. The structure of its free part is very complex (Linke, Ivemeyer, Mundel, Stockmeier, & Kolmerer, 1998). Different muscles exhibit different titin isoforms with different elastic properties (Prado et al., 2005). It is very interesting, if these isoforms are exclusively determined by the genotype, or may adapt dependent on muscle function or specific training programs as suspected by (Lindstedt et al., 2002; McBride, Triplett-McBride, Davie, Abernethy, & Newton, 2003). A differential expression of titin protein bands in competitive athletes with increased levels of strength and power in comparison to untrained non-athletic individuals was observed by McBride et al. (2003). However, Kyrolainen et al. (2005) found no changes in the titin isoforms isolated from muscle biopsies after 15 weeks plyometric training. So far, further studies are needed to analyse modifications in the fine structure of the contractile and elastic components to find true mechanistic explanations due to plyometric training.

A limitation of this exercise study is that no control group was available. It takes the next step, a homogeneous comparison group of rock and roll dancers to be consulted, which is difficult to implement due to the availability in the rule.

5. Conclusion

In conclusion plyometric training leads to an increased number of rock’n’roll kicks. This increase might be attributed to gains in reactive strength as we found in our study. Despite considerable improvements in jumping performance, in dynamic peak torque as well as work during maximal concentric contractions, the results from this investigation do not reveal any further information about possible adaptations in muscle structure or neural drive of the plantar flexors. However, we suggest the implementation of plyometric training to improve the sport specific performance in rock’n’roll dancing.

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