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# The improvement of suspension training for trunk muscle power in Sanda athletes



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## ABSTRACT

The aim of this study was to investigate whether both suspension training (ST) and traditional training (TT) can improve Sanda athlete's strength quality of trunk muscles and to explore the effect of suspension training on Sanda athletes' trunk muscle power production. Twelve elite Sanda athletes from the Competitive Sports School of Shanghai University of Sport were randomly assigned to experimental group (EG) and control group (CG). EG and CG were regularly trained with suspension training and traditional strength training for 40 minutes three times per week. The total duration of training was 10 weeks. The measurements including peak torque (PT), PT/body weight (BW), and rate of force development (RFD) were used to assess trunk muscles strength. The results showed that there were significant differences between the two groups' performance when it was tested at the higher velocity of dynamometer (test of muscle power), but less significant differences when the two groups performance was tested at the lower velocity of dynamometer (test of maximum strength). The conclusion of this study is that compared with traditional training methods, suspension training can improve back and trunk flexion muscles strength more effectively. In particular, suspension training can improve the explosive power of trunk extension and flexion muscles.

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## 1. Introduction

Sanda, also called San Shou, is a form of Chinese boxing. It is a martial art which was originally developed by the Chinese military based on combining the study and practices of traditional Kung fu with modern combat fighting techniques. Sanda is a highly confrontational sport. It combines full-contact kickboxing, which includes close range and rapid successive punches and kicks, with wrestling, takedowns, throws, sweeps, kick catches, and, in some competitions, even elbow and knee strikes. Its rapid development has recently led to the establishment of the Chinese National Championships, the World Championships, and the World Cup.<sup>1</sup>

Similar to Wrestling, Judo, and Taekwondo, Sanda competitors

not only require an absolute strength, but also need to have explosive speed and strength. This ability to produce force quickly or at fast speeds is the most valuable factor that enables athletes to succeed during competitions.<sup>1–3</sup> In Sanda, if athletes want to win the competition, they need to seize the transient opportunities, accordingly take timely offensive or defensive actions, and, at the same time, they also need to control their center of gravity well, maintaining good balance and stability.<sup>2,3</sup> However, during actual competitions, many players often experience difficulties in using strength even though they have good limb strength. The main cause of which is that these athletes have insufficient trunk (core) strength. For Sanda athletes, one of the key factors to winning depends on the quality of strength in trunk flexion and extension muscles, especially the mechanical power of those muscles.<sup>2,3</sup>

In previous Sanda related studies, researchers have published several articles mainly focused on the characteristics of upper and lower limb muscle strength of athletes.<sup>1,4–7</sup> However, while the

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importance of the trunk region was indicated in other sports, there is limited research on the trunk muscles of Sanda athletes.<sup>3,8–10</sup>

Suspension training (ST) combines dynamic and static training by suspending specific parts of the body with a suspension sling to improve the stability and coordination of muscle groups. In recent years, ST has attracted more and more attention from scholars, coaches, and athletes for its positive effect on muscular strength and function.<sup>11–15</sup> Increasingly, ST has also been applied in competitive sports training and injury prevention. Nonetheless, while ST has been applied to a wide range of activities, studies of its application to Sanda athlete strength training were not found in the currently published literature. The purpose of this study was to explore the effects of different training methods of trunk flexion extension and extend trunk flexion extension strength by applying ST to elite Sanda athletes. As a result, this research can serve as a reference for future improvements of Sanda Athlete's strength training.

In this study, we hypothesized that both suspension and traditional strength training would exhibit benefits to the development of trunk muscle strength, but suspension training would be more effective than traditional strength training in improving trunk muscle power.

## 2. Methods

### 2.1. Subjects

The participants were 12 elite Sanda athletes from the Competitive Sport School of the Shanghai University of Sport. All the participants in this study were top Sanda players. The number of such players was small, and they came from different provinces. This study took the advantage of a training camp held by Shanghai University of Sport and selected 12 top-notch players as the participants. According to drawing lots, these participants were randomly assigned to the experimental group (EG) and control group (CG). The age, height, body mass, and training periods in the EG group were  $19.00 \pm 1.50$  years,  $171.70 \pm 6.20$  cm,  $66.50 \pm 7.30$  kg, and  $4.83 \pm 0.50$  years, respectively. Respectively, in the CG these athletes' measurements were  $18.70 \pm 1.60$  years,  $172.80 \pm 5.30$  cm,  $67.17 \pm 5.50$  kg, and  $5.00 \pm 1.30$  years. There were no significant differences between the two groups in age, height, mass and

training periods ( $p = 0.724$ ,  $p = 0.733$ ,  $p = 0.862$ ,  $p = 0.828$ ). All athletes were healthy and free of any apparent neuromuscular injury or impairment, which was verified by their annual physical examination and confirmed by their doctor. The study was approved by the university ethical review committee. Informed consent forms were signed after the participants were informed of the details of the study and the associated risks (see Table 1).

### 2.2. Design

The EG and CG received traditional training (TT) and ST respectively in the Sanda Hall of the Shanghai University of Sport for a period of 70 training days. The participants performed warm-up and stretching exercises for 10 minutes before the traditional training (TT) or suspension training (ST) in every training section. The training frequency was 3 times per week, the exercise load was 30s–40s  $\times$  3, the interval rest time was 30 seconds, and the training time was 30 minutes each.

**Experimental group (EG):** Participants received ST which consisted of two phases.<sup>16,17</sup> Phase 1: two legs suspended with weight on two elbows (Fig. 1), then single leg suspension (left or right) with weight on two elbows (Fig. 2), followed by lateral single leg suspension (left or right) with weight on one elbow (Fig. 3). After receiving instructions and training on components of this phase, the subjects continued to train independently for the rest of the training period. Phase 2: combining ST with Sanda, included two legs suspension with either of the hands supporting in turn (Fig. 4), two legs suspension with hip and knees flexion (Fig. 5), two legs suspension with hands supporting and pulling stomach to form a V shape (Fig. 6) (see Table 2).

**Control group (CG):** Based on the related Sanda training information and the recommendations from relevant experts, this group was trained with traditional core strength training methods, which included plank exercises, prone single leg exercises, side-lying leg lift exercises, holding onto wall bars and lifting legs, lateral flexion with a dumbbell, and barbell twisting. The complete list is showed in the following Table 3.<sup>18,19</sup>

### 2.3. Equipment

This research adopted the method of isokinetic test of trunk flexion and extension, because the isokinetic test provides the most objective and accurate measures of muscle strength.<sup>1,20</sup> The data from the trunk flexion and extension strength measurements was collected with a Con-trex MJ dynamometer (Human Kinetics 1.7.1, CMV AG, Switzerland) at velocities of  $60^\circ/\text{s}$  (low) and  $180^\circ/\text{s}$  (high) based on previous studies.<sup>21,28,30</sup> The velocity of  $60^\circ/\text{s}$  was mainly used for maximum strength test, while the fast-isokinetic test at the velocity of  $180^\circ/\text{s}$  or above was mainly used for muscle power test.

**Table 1**  
Descriptive data of participants (Means  $\pm$  SD).

	EG (n = 6)	CG (n = 6)	t	p
Age (year)	19.00 $\pm$ 1.50	18.70 $\pm$ 1.60	0.363	0.724
Height (cm)	171.70 $\pm$ 6.20	172.80 $\pm$ 5.30	−0.351	0.733
Weight (kg)	66.50 $\pm$ 7.30	67.17 $\pm$ 5.50	−0.178	0.862
Training periods (year)	4.83 $\pm$ 0.50	5.00 $\pm$ 1.30	−0.222	0.828

Note: EG, experimental group; CG, control group.

**Table 2**  
Suspension training schedule for experimental group.

Training phases	Training objectives	Training days	Training methods	Training load	Interval break time
Phase 1	Enhance the strength and excitability of the deep tiny muscles and improve the stability of the core muscles	Mon.	two legs suspension with weight on two elbows	30s–40s $\times$ 3	30s
		Wed.	single leg suspension (left or right) with weight on two elbows	30s–40s $\times$ 3	30s
		Fri.	single leg suspension (left or right) with weight on one elbow	30s–40s $\times$ 3	30s
Phase 2	To improve the mechanical power of core muscles through unstable training	Mon.	two legs suspension with either of the hands supporting in turn	16–18 $\times$ 3	30s
		Wed.	two legs suspension with hip and knees flexion	16–18 $\times$ 3	30s
		Fri.	two legs suspension with hands supporting and pulling in stomach to form V shape	16–18 $\times$ 3	30s



Method: face the floor with two legs suspending at the height of 30 cm and with weight on two elbows.

**Fig. 1.** Two legs suspended with weight on two elbows.



Method: face the floor with one leg suspending at the height of 30 cm and keep the other leg at the same height, but not in suspension.

**Fig. 2.** Single leg suspension (left or right) with weight on two elbows.

#### 2.4. Testing protocol

Based on the standard procedure of an isokinetic test, participants performed abdominal warm-up exercise for 10 minutes before the test.<sup>1,22</sup> It included waist flexion, lateral flexion, waist stretching and rotation. It was followed by three submaximal isokinetic contraction exercises with the dynamometer to familiarize the participants with the isokinetic muscle strength testing modes.

The testing was recorded at the velocities of 60 °/s and at 180 °/s. At each velocity, the subjects flexed their muscles up and down 5 times with their greatest strength. The test data was automatically recorded and saved by the dynamometer.

The trunk extension (PTex) and flexion (PTfl) peak torque (Nm) were calculated as the average of the maximum force of the first three trials. Relative trunk extension (PTexr) and flexion (PTflr) peak torque were then normalized by body mass (Nm/kg), and





Method: keep one side of the body downward, with weight on one elbow and one leg suspending at the height of 30 cm and raise the other leg.

**Fig. 3.** Lateral single leg suspension (left or right) with weight on one elbow.



Method: first, keep suspension pose with two feet on the band and with weight on two palms until the position is stable. Then, raise one arm upward and backward as much as possible and keep the maximum crest for two or three seconds, and then slowly lower the raised arm back the original position. After that change to the other arm and repeat the same movement with the other arm.

**Fig. 4.** Two legs suspension with either of the hands standing in turn.

were calculated as  $PT_{\text{ex}}$  (or  $PT_{\text{fl}}$ ) divided by the participant's body mass.<sup>23</sup> Rates of force development (Nm/s) for extension (RFD<sub>ex</sub>) and flexion (RFD<sub>fl</sub>) were calculated as the ratio of the maximum torque attained during the repetitions and the duration that it took to reach the peaks.

## 2.5. Statistical methods

The data from isokinetic muscle strength tests were analyzed with SPSS22.0 statistical package (SPSS Inc., Chicago, IL, USA), and the results of the analysis are presented below. Descriptive



Method: first, keep the position with legs in suspension and with the weight on the two fists. Then flex the two knees forward as much as possible (do not move the upper part of the body), and then extend the legs back to the original position. Repeat the same movements.

**Fig. 5.** Two legs suspension with hip and knees flexion.



Method: keep the position with legs in suspension and extend the body parallel to the floor, then fold the body into the V shape. After that slowly unfold the body to the original position.

**Fig. 6.** Two legs suspension with hands supporting and pulling stomach to form a V shape.

statistics (mean, standard deviation, and range) were calculated for each angle of measurement for both isometric flexion and extension. In order to see the between group differences the MANOVA was used to compare the main effects of time (pre and post-intervention), group (EG and CG) and their interaction (time-by-

group) on the isometric flexion and extension data (i.e., P<sub>Tex</sub>, P<sub>Tfl</sub>, P<sub>Texr</sub>, P<sub>Tflr</sub>, R<sub>FDex</sub>, R<sub>FDfl</sub>). The effect size was expressed as a partial eta-squared ( $\eta^2$ ) to determine the magnitude of the effect when a significant main and interaction effects was reached. It was interpreted according to Stevens<sup>24</sup> with  $\eta^2 = 0.01$  as corresponding to a



**Table 3**  
Traditional core strength training schedule for control group.

Training phases	Training objectives	Training day	Training methods	Training load	Interval break time
Phase 1	Enhance the strength of the muscles and improve the stability of the core muscles	Mon.	plank exercises	30s–40s × 3	30s
		Wed.	prone single leg exercises	30s–40s × 3	30s
		Fri.	side-lying leg lift exercises	30s–40s × 3	30s
Phase 2	Enhance the dynamic exercise and improve the mechanical power	Mon.	holding wall bars and lifting legs	16–18 × 3	30s
		Wed.	lateral flexion with a dumbbell	16–18 × 3	30s
		Fri.	barbell twisting	16–18 × 3	30s

small effect size,  $\eta^2 = 0.06$  to a medium effect size, and  $\eta^2 = 0.14$  to a large effect size. The MANOVA was followed by a one-way ANOVA to further test the significance of main effects and to see where the difference lies. In other words, ANOVA assess the difference between the groups for any of the dependent variables, or each of the isometric flexion and extension data (i.e., PTex, PTfl, PTexr, PTflr, RFDex, RFDfl). This procedure has been suggested by Schutz and Gesaroli<sup>25</sup> as one of the techniques to reduce the Type I error rate. In some cases, even though significant differences might be detected by the MANOVA test, none of the ANOVA tests may show a significant difference. Therefore, performing a MANOVA and following up on the results with a one-way ANOVA is meant to correct this problem. An alpha level of .05 was used to determine the statistical significance for MANOVA and each ANOVA (Table 3).

**3. Results**

The results showed a significant multivariate effect at the velocity of 180°/s, but less significant multivariate effect at the velocity of 60°/s. Table 4 displays the means of groups and time at different velocities.

As can be seen in Table 4, at the velocity of 180°/s, the results revealed a significant effect for groups [F (6,15) = 5.023,  $p < .005$ ,  $\eta^2 = .668$ ], indicating a difference between EG and CG. A significant effect was also observed for time [F (6,15) = 6.597,  $p < .001$ ,  $\eta^2 = .73$ ], indicating a difference between pre and post-intervention performance. Moreover, an interaction effect of group and time was observed [F (6,15) = 3.54,  $p < .022$ ,  $\eta^2 = .586$ ], indicating a difference in both group and time dimensions. Therefore, we can conclude that at the velocity of 180°/s the performance was significantly dependent on type of training and its duration ( $p < 0.05$ ).

At the velocity of 60°/s, the results revealed a significant effect for time [F (6,15) = 4.463,  $p < .009$ ,  $\eta^2 = .641$ ], indicating a difference between pre and post-intervention performance. However, the interaction between group and time was nonsignificant [F (6,15) = 1.267,  $p < .329$ ,  $\eta^2 = .336$ ], and the effect of group was not significant [F (6,15) = 1.358,  $p < .293$ ,  $\eta^2 = .352$ ]. This means that when measured at the low velocity of dynamometer there was no statistically significant difference between EG and CG, and also no statistically significant difference between these groups pre and

**Table 4**  
MANOVA results.

		Effect	Vlue	F(6,15)	Sig	$\eta^2$
180°/s	GROUP	Pillai's Trace	.668	5.023 <sup>b</sup>	.005*	.668
	TIME	Pillai's Trace	.725	6.597 <sup>b</sup>	.001*	.725
	GROUP * TIME	Pillai's Trace	.586	3.540 <sup>b</sup>	.022*	.586
60°/s	GROUP	Pillai's Trace	.352	1.358 <sup>b</sup>	.293	.352
	TIME	Pillai's Trace	.641	4.463 <sup>b</sup>	.009*	.641
	GROUP * TIME	Pillai's Trace	.336	1.267 <sup>b</sup>	.329	.336

\*Significant difference between groups( $p < 0.05$ ).  
PTex = peak torque of trunk extension; PTfl = peak torque of trunk flexion;  
PTexr = PTex/BW; PTflr = PTfl/BW.

**Table 5**  
One-way ANOVA for post-intervention results.

Variables	Groups		F	p
	EG	CG		
180°/s PTfl	259.81 ± 10.63	216.68 ± 34.91	8.379	.016*
180°/s PTex	358.22 ± 36.57	249.70 ± 47.95	19.433	.001*
180°/s PTflr	3.95 ± 0.47	3.26 ± 0.63	4.567	.058
180°/s PTexr	5.45 ± 0.90	3.71 ± 0.61	15.252	.003*
180°/s RFDfl	11.18 ± 1.71	9.07 ± 1.90	14.379	.004*
180°/s RFDex	16.36 ± 3.53	10.30 ± 1.67	4.345	.048*
60°/s PTfl	242.11 ± 30.28	221.48 ± 18.62	2.020	.186
60°/s PTex	378.51 ± 59.43	261.72 ± 43.06	15.194	.003*
60°/s PTflr	3.66 ± 0.47	3.32 ± 0.40	0.107	.750
60°/s PTexr	5.76 ± 1.16	3.91 ± 0.64	0.192	.670
60°/s RFDfl	8.19 ± 2.05	6.41 ± 1.07	0.536	.481
60°/s RFDex	11.54 ± 3.88	7.11 ± 1.55	3.788	.080

\*Significant difference between groups( $p < 0.05$ ).  
EG, experimental group; CG, control group.  
PTex = peak torque of trunk extension; PTfl = peak torque of trunk flexion;  
PTexr = PTex/BW; PTflr = PTfl/BW.

post-intervention. Therefore, we can conclude that at the velocity of 60°/s the difference in performance was only due to the duration of training ( $p < .05$ ).

Because the results with MANOVA analysis were significant, we continued further analyzing with one-way ANOVA. Table 5 summarizes the results of the one-way ANOVA performed on post-intervention data.

We found that there were significant differences between groups at the velocity of 180°/s, with PTfl ( $F(1,11) = 8.379, p = .015$ ), PTex ( $F(1,11) = 19.433, p = .001$ ), PTexr ( $F(1,11) = 15.242, p = .003$ ), RFDfl ( $F(1,11) = 14.379, p = .004$ ), RFDex ( $F(1,11) = 4.345, p = .048$ ). This indicated that ST had a significant effect on trunk flexion and extension, relative extension, and rates of force development for flexion and extension. The only not significant statistical difference at the velocity of 180°/s was PTflr ( $F(1,11) = 4.567, p = .058$ ). This indicated that there were no statistically significant differences in relative trunk flexion muscle training between EG and CG.

In comparison, there were no statistically significant differences between the two groups at the velocity of 60°/s, with PTfl ( $F(1,11) = 2.020, p = .186$ ), PTflr ( $F(1,11) = 0.107, p = .750$ ), PTexr ( $F(1,11) = 0.192, p = .670$ ), RFDfl ( $F(1,11) = 0.536, p = .481$ ), RFDex ( $F(1,11) = 3.788, p = .080$ ). This indicated no significant differences between the two groups in trunk flexion, relative flexion and extension, and rates of force development for flexion and extension at lower velocity. The only significant difference at the velocity of 60°/s was for PTex ( $F(1,11) = 15.194, p = .003$ ). It indicated that ST had a significant effect on the trunk extension muscles.

Based on these findings, we can say that most notable differences between groups are at high velocity, indicating a significant effect of ST on muscle power. At lower velocity, the performance of the two groups is relatively similar, but at higher velocity ST was able to significantly enhance the EG's performance. As one other study demonstrated,<sup>26</sup> ST was able to improve operation efficiency and mechanical power of trunk flexion and extension. Moreover, at

both velocities of dynamometer or there were statistically significant differences between groups in trunk extension muscles (PTex) performance, which indicated the enhanced strength of back muscles in EG.

#### 4. Discussion

The purpose of this study was to investigate whether both suspension training (ST) and traditional training (TT) can improve Sanda athlete's strength quality of trunk flexion and extension, and whether suspension training is more effective than traditional strength training for trunk muscle power. Main effects were found for the type of training and time. In the present study, the results showed that both suspension training and traditional strength training exhibit benefits to trunk muscle strength development, but that suspension training was more effective for the explosiveness of trunk flexion and extension. This would indicate that ST is better at developing muscle power. Our finding is important because no studies have focused on the strength training of Sanda athletes in suspension training.

It has been reported that general strengthening of the trunk musculature can not only enhance overall fitness, but also further specific exercise goals. The abdominal muscles strength quality is an important factor for all kinds of athletes.<sup>27</sup> However, our research has the most practical value for Sanda athletes. It has indicated that both suspension training and traditional training all contribute to development of abdominal and back muscle strength, but research data shows that the traditional training group did not show much improvement in back strength. This is because in the traditional training the types of exercises pay excessive attention to the training of abdominal muscles while ignoring the muscles of the back.<sup>14</sup>

According to Karatas,<sup>21</sup> peak torque and relative peak torque are reliable indicators of the quality of the abdomen strength and can reflect the strength of trunk flexion and extension muscles. Moreover, the relative peak torque value can also be regarded as a reference index reflecting the muscle power.<sup>7,22,24,27–29</sup> After 10 weeks of training the performance of experimental and the control group was compared with the performance before the training. All the indicators of the experimental group have significantly changed. They showed that suspension training can be more efficient at building the trunk (core) strength, including back and abdominal muscles. In comparison, the traditional training method was less efficient in the training of back strength. According to the Rochongar, suspension training can improve the abdominal muscles' work efficiency and improve the explosive force of the abdominal muscles.<sup>26</sup> In particular, almost all the PT/BW indexes of EG had significant results in terms of muscle power. This indicated that ST was helpful in optimizing the strength quality of individuals' trunk flexion and extension, especially when evaluated in terms of the explosive power of trunk flexion and extension.

Similar to our findings, several studies report an increased challenge to abdominal wall activation with the instability of training devices.<sup>30–34</sup> This is primarily because of an increased force production and higher load displacement when the exercises were performed in an unstable environment.

In our study, there was a positive effect of ST on the strength of the back muscles in the experimental group. This also corresponds with similar findings in other studies.<sup>10,35–37</sup> Moreover, significant differences in rates of force development (RFD) variables were found between two groups. RFD reflects the relationship between the maximum strength and the duration maintained by the individual who is making his maximum isometric contraction.<sup>38</sup> It indicates the increase of strength in unit time, i.e. the ability to produce bigger forces in a short period or the ability to explode

force.<sup>31</sup> The RFD of core muscles is PT divided by PT time because Sanda athletes are classified into different weight groups. This shows that suspension training not only can improve the strength of the abdominal muscles, but can also improve the strength of the back muscles.

A few methodological limitations of our study should be taken for consideration. This study had a small number of participants, and the participants only included male Sanda athletes which might limit our research findings generalizability. The experiment took advantage of a training camp held by Shanghai University of Sport and selected 12 top-notch players as the participants. In general, the number of such athletes is small at universities. However, the advantage of the training camp was that participants came from different provinces. In the future, it will be best to increase the sample size. In addition, future research should prolong the duration of intervention and expand the measurement contents.

#### 5. Conclusion

Compared with traditional training methods, suspension training could improve back and trunk flexion muscles strength effectively. In particular, suspension training can improve the explosive power of trunk extension and flexion muscles.

#### Authors' contributions

CJ, XM, AL, WS and PM searched the related studies and contributed to the writing of this manuscript. XM drafted the original article. AL modified all the tables and figures. CJ participated in the study design and made comments to the manuscript. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

#### Conflict of interests

None of the authors declare competing financial interests.

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