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Original article

Determination of biomechanical differences between elite and novice San Shou female athletes

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Abstract

Determining the key factors in athletic performance is important for developing the technique and strength of athletes. Many martial arts forms have been studied, but a relatively new form of martial arts competition, San Shou, has not been analyzed. The purpose of this study was to determine key attributes necessary in the development of the San Shou athlete, particularly in female participants. Six elite and six novice competitors performed 30 continuous repetitions of cyclic extension and flexion of the trunk segment, knee joints, and elbows joints at two velocities, 60°/second and 180°/second, using an isokinetic dynamometer. Variables of interest were maximum torque production, normalized torque (Nm/kg), fatigue indexes (average of three maximal forces in the first three cycles/average of maximal forces in the last three cycles), and rate of torque development (Nm/s). Results indicate significant differences between groups only during trunk flexion for maximum torque, normalized torque, and rate of force development, whereas differences between movement velocities were apparent for multiple variables at each anatomic region. These analyses assist in providing further information regarding the possible key factors in developing the San Shou female athlete. Further work is required to identify additional parameters in developing the San Shou athlete.

Keywords: Athletes; Biomechanics; Force; Martial arts; San Shou

Introduction

San Shou, a popular form of free boxing that originated in China, is a highly confrontational sports competition. Its rapid development has recently led to the establishment of the Chinese National Championships, World Championships, and World Cup. The technical level of the female competitors has been similar to that of male San Shou athletes. Strength and related body conditioning such as power and speed are the keys to the success of many sports, especially San Shou. Although skill development in San Shou is important, strength and power are also valuable factors enabling athletes to be successful during international competition.[1,2] Although research pertaining to many other forms of martial arts is available,[3–6] research analyzing the performance and training of San Shou athletes is lacking. Compared with other martial arts forms, such as Judo and Taekwondo, San Shou relies more on upper extremity strength and power, which requires the trunk and lower extremity to provide a solid base that enables the arms and hands to move quickly and powerfully. In addition, trunk/waist muscle may also be part of the punch delivery system. Therefore, the upper extremity, as well as trunk strength and power, might be more important to San Shou athletes compared with athletes participating in a different form of martial arts.

Isokinetic dynamometry testing has been a reliable and validated means of testing athletic strength variables. Many isometric research protocols have been used to maintain specific joint positions to test muscle strength after strength training,[7–9] fatiguing,[10] or passive motion.[11] These tests are

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assumed to transfer to dynamic movement, but may not provide specific clues regarding athletic performance.[12] Isokinetic testing allows for isolation of the limb in pseudostatic or dynamic ranges of motion while focusing on the function movement of the segment or limb.[13–15] Isokinetics is also dependent on the contraction speed and muscle length relationships in determining performance. Further, isokinetic testing enables researchers to examine details of the muscle function parameters and the torque development trajectories.

In this article, we used isokinetic muscle strength testing to examine elite and novice women San Shou athletes. The purpose of this study was to identify strength characteristics of female athletes in this sport. Knowledge gained during this study can then be applied to aid women San Shou athletes in strength and conditioning training, improve training efficiency, and contribute to scientific advances in martial arts training.

Methods

Participants

Two groups of athletes were recruited for the study (elite and novice athletes, $n = 6$, each group). The elite group consisted of six women from the Shanghai women San Shou team who were tested after a 3-month winter training regimen was completed. Novice participants were recruited from a healthy, physically active college student population. All participants performed similar training exercises and volumes during the conditioning sessions. The age, height, body mass, and training years for the elite group were 23.5 ± 2.4 years, 167.0 ± 5.5 cm, 63.7 ± 6.9 kg, and 5.3 ± 1.2 years, respectively. The age, height, body mass, and training years for the novice athletes were 17.0 ± 0.9 years, 162.8 ± 7.4 cm, 58.7 ± 5.3 kg, and 2.5 ± 0.5 years, respectively. All athletes were healthy and free of any apparent neuromuscular injury or impairment. The study was approved by the university ethical review committee. Informed consent forms were signed after all questions from the participants were answered.

Equipment

Torque and angular velocity data were collected using a Con-Trex MJ dynamometer (Human Kinetics 1.7.1, CMV AG, Switzerland). Muscular strengths of the extensors and flexors of the trunk segment, knee joints, and elbow joints were assessed using the dynamometer. Flexion and extension strengths were tested at velocities of 60°/second and 180°/second. The dynamometer was calibrated prior to each testing session.

Testing protocol

Participants performed a 10-minute warm-up routine on a stationary bicycle at their preferred pace. Tests were completed in a pseudorandom order for sides at the knee and elbow, and between testing segments. Each test was repeated 30 times continuously while performing isokinetic concentric contractions in flexion and extension reciprocally at 60°/second and 180°/second. Range of motion for the back was determined from an upright standing position to 90° of trunk flexion. The trunk was secured to the closed chain attachment during flexion and extension movements. During knee and elbow joint tests participants were seated in the Con Trex chair and secured into position with a harness system. The knee range of motion was determined from full extension (0°) to 120° of relative flexion, whereas the elbow range of motion was determined in a manner similar to that of the knee, but deviated 160° in flexion. Participants performed movements at 60°/second followed by movements at the 180°/second velocity per limb. These efforts were then followed by test performances on the contralateral limb. Rest intervals between velocity conditions (60°/second and 180°/second) were 60 seconds, and between sides were 5 minutes. All test results were stored in a computer for future analyses.

Maximum extension (Tmex) and flexion (Tmfl) torque (Nm) were calculated as the average of the maximum force of the first three trials. Maximum extension (Tmexm) and flexion (Tmflm) torque normalized by body mass (Nm/kg) were calculated as Tmex (or Tmfl) divided by the participant's body mass. Fatigue indexes for both extension (FIex) and flexion (FIfl) were calculated as the ratio of the average peak values of the first three trials to the average peak of the last three trials. Rates of force development (Nm/s) for extension (RFDex) and flexion (RFDfl) were calculated as the ratio of the maximum torque attained during the repetitions and the duration that it took to reach the peaks.

Statistical analyses

The Levene test was used to examine group and velocity differences in all dependent variables. Interaction effects were also examined at each level of joint/segment testing. Data were normally distributed and all statistical analyses were tested at a significance level of 0.05.

Results

Group differences were apparent during movements of the trunk for Tmfl ($F_{1,5} = 11.33$, $p < 0.03$), Tmflm ($F_{1,5} = 7.20$, $p < 0.05$), and RFDfl variables ($F_{1,5} = 14.70$, $p < 0.02$) (Table 1). There were also differences between the velocity conditions for Tmex ($F_{1,5} = 15.20$, $p < 0.02$), Tmfl ($F_{1,5} = 25.25$, $p < 0.005$), Tmexm ($F_{1,5} = 15.81$, $p < 0.02$), Tmflm ($F_{1,5} = 27.24$, $p < 0.01$), and RFDfl ($F_{1,5} = 6.71$, $p < 0.05$) (Table 2). There were no significant group and velocity interaction effects observed.

Group differences were not observed during knee flexion-extension. There were significant differences between velocity conditions for variables Tmex ($F_{1,5} = 39.09$, $p < 0.01$), Tmfl ($F_{1,5} = 80.01$, $p < 0.001$), Tmexm ($F_{1,5} = 37.35$, $p < 0.002$), Tmflm ($F_{1,5} = 78.25$, $p < 0.001$), FIex ($F_{1,5} = 11.01$, $p < 0.03$), RFDex ($F_{1,5} = 53.74$, $p < 0.001$), and RFDfl ($F_{1,5} = 8.68$, $p < 0.04$) (Table 3). No significant

Table 1
Comparison (mean ± SD) of torque, normalized torque, fatigue indexes, and rates of force development of trunk extension and flexion movements between groups.

Variable	Group 1		Group 2	
	Mean	SD	Mean	SD
Tmex	265.0	27.6	227.9	49.2
Tmfl*	152.0	31.6	99.5	20.2
Tmexm	4.22	0.76	3.86	0.61
Tmflm*	2.41	0.53	1.70	0.34
FIex	0.951	0.55	0.699	0.41
FIfl	0.679	0.24	0.469	0.18
RFDex	575.1	86.6	558.5	138.0
RFDfl*	344.5	156.6	160.4	66.8

*Significant differences between groups.
FIex = fatigue index for extension; FIfl = fatigue index for flexion; RFDex = rate of force development for extension; RFDfl = rate of force development for flexion; SD = standard deviation; Tmex = maximum extension; Tmexm = maximum extension torque; Tmfl = maximum flexion; Tmflm = maximum extension flexion torque.

group and velocity interaction effects or bilateral differences were observed.

Group differences were not observed during the elbow flexion-extension movements. There were significant differences between velocity conditions for variables Tmex ($F_{1,5} = 15.11$, $p < 0.02$), Tmfl ($F_{1,5} = 11.05$, $p < 0.03$), Tmexm ($F_{1,5} = 13.41$, $p < 0.02$), Tmflm ($F_{1,5} = 10.18$, $p < 0.03$), FIex ($F_{1,5} = 7.89$, $p < 0.04$), FIfl ($F_{1,5} = 32.85$, $p < 0.003$), and RFDfl ($F_{1,5} = 36.17$, $p < 0.002$) (Table 4).

Discussion

The purpose of this study was to examine selected variables, namely strength and power, that were deemed important in determining performance in San Shou martial arts boxing. The level of experience was a determining factor at only one body segment, whereas differences in torque output during relatively slow and fast movements were the only other changes denoted. This finding has significance because the ability of the athlete to maintain a high level of fatigue resistance is important to the performance outcome.

The between-group differences are insightful and point toward factors that influence athletic performance. The maximum torque output and rate of torque development of the trunk flexors seem to be the key indicators of determining differences in elite and novice San Shou athletes. To be successful, elite athletes require greater trunk flexion power. These results are significant to understanding the emphasis training programs that San Shou athletes should employ. These data also provide further support for long-term neuromuscular adaptations of the abdominal muscles in this highly skilled sport. The trunk flexors are activated to initiate the performance of attack and defensive techniques while also assisting in maintaining the stability of the trunk. It has been reported that a general strengthening of the trunk musculature can enhance overall fitness and specific exercise goals.[16] Athletes must also practice sport-specific exercises because trunk rotations and lateral flexions are common in the martial arts.[6]

Table 2
Comparison (mean ± SD) of torque, normalized torque, fatigue indexes, and rates of force development during trunk extension and flexion movements between velocities.

Variable	60°/s		180°/s	
	Mean	SD	Mean	SD
Tmex*	259.2	39.5	233.7	45.0
Tmfl*	136.2	38.3	115.3	34.9
Tmexm*	4.25	0.60	3.83	0.76
Tmflm*	2.23	0.59	1.88	0.51
FIex	0.696	0.43	0.954	0.53
FIfl	0.598	0.27	0.551	0.21
RFDex	532.2	107.6	601.4	111.8
RFDfl*	281.3	176.3	223.6	120.7

*Significant differences between velocities.
FIex = fatigue index for extension; FIfl = fatigue index for flexion; RFDex = rate of force development for extension; RFDfl = rate of force development for flexion; SD = standard deviation; Tmex = maximum extension; Tmexm = maximum extension torque; Tmfl = maximum flexion; Tmflm = maximum extension flexion torque.

Table 3
Comparison (mean ± SD) of torque, normalized torque, fatigue indexes, and rates of force development during knee flexion and extension between velocities.

Variable	Vel = 60°/s		Vel = 180°/s	
	Mean	SD	Mean	SD
Tmex*	156.4	33.8	127.9	26.4
Tmfl*	80.36	14.3	62.67	15.8
Tmexm*	2.57	0.53	2.11	0.45
Tmflm*	1.32	0.25	1.04	0.31
FIex*	0.640	0.29	0.959	0.40
FIfl	0.612	0.19	0.729	0.26
RFDex*	375.6	94.3	492.9	112.4
RFDfl*	160.6	51.1	224.5	102.9

*Significant differences between velocities.
FIex = fatigue index for extension; FIfl = fatigue index for flexion; RFDex = rate of force development for extension; RFDfl = rate of force development for flexion; SD = standard deviation; Tmex = maximum extension; Tmexm = maximum extension torque; Tmfl = maximum flexion; Tmflm = maximum extension flexion torque; Vel = velocity.

Table 4
Comparison (mean ± SD) of torque, normalized torque, fatigue indexes, rates of force development during elbow extension, and flexion movements between velocities.

Variable	60°/s		180°/s	
	Mean	SD	Mean	SD
Tmex*	38.31	12.6	29.53	10.3
Tmfl*	33.86	7.4	28.40	6.90
Tmexm*	0.636	0.23	0.487	0.17
Tmflm*	0.555	0.12	0.464	0.10
FIex*	0.239	0.16	0.311	0.16
FIfl*	0.178	0.10	0.283	0.11
RFDex	46.53	22.2	76.77	54.5
RFDfl*	52.18	24.7	84.28	32.9

*Significant differences between velocities.
FIex = fatigue index for extension; FIfl = fatigue index for flexion; RFDex = rate of force development for extension; RFDfl = rate of force development for flexion; SD = standard deviation; Tmex = maximum extension; Tmexm = maximum extension torque; Tmfl = maximum flexion; Tmflm = maximum extension flexion torque.

The physiological and biomechanical differences between experienced and less-experienced martial arts athletes have been reported. Little[17] indicated very few differences between novice and elite women's martial arts athletes, whereas Toskovic et al[18] reported significant strength differences between these groups. Likewise, strength differences have been reported between elite and novice groups of martial arts athletes,[19] whereas differences between top-level and reserve national athletes are not present.[3] Our observations provided more detailed, i.e., stronger and more powerful trunk flexion information about elite San Shou athletes.

The rate of movement performance did not play a role in determining differences between athletic groups, but did provide data distinguishing between joints. For all three areas of the body, peak torque in flexion and extension, peak torque normalized to body mass, and RFDfl were all significantly different between velocity conditions. Theoretically, as the speed of muscle contraction increases, the force output of the muscle is reduced, indicating an inverted relationship between force and velocity during a concentric movement. Rate of force development from the trunk flexion movement followed this relationship as a reduction occurred from 60°/second to 180°/second (Table 2). Contrary to this relationship, when rate of force development was significant in knee and elbow flexion and knee extension, there was an increase from 60°/second to 180°/second (Tables 3 and 4). This could be interpreted either as higher forces being attained in a similar time period, or maximal force attained in a reduced amount of time. Likewise, the fatigue indexes for knee and elbow flexion and elbow extension increased from 60°/second to 180°/second (Tables 3 and 4), indicating a potentially higher resistance to fatigue at these higher movement velocities. In isometric conditions, rate of force development during maximal and submaximal force outputs has been reported to increase with a reduction in effort duration.[20] However, short-term resistance training does significantly influence a change in rate of force development.[9,21,22] The training that these athletes perform, using quick, high-magnitude force movements, may explain the results obtained.

In conclusion, San Shou martial arts athletes have similar characteristics across skill developmental levels. The difference in trunk flexor variables between these groups may offer further insight into the training mode and experience required to become an elite athlete in San Shou competition.

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