Effects of High Intensity Intermittent Badminton Multi-Shuttle Feeding Training on Aerobic and Anaerobic Capacity, Leg Strength Qualities and Agility

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Abstract: Despite the fact that High Intensity Intermittent Training (HIIT) resulted in physiological adaptations and started to be applied on racket sport, the effectiveness of HIIT in a multi-shuttle feeding form to improve physical performance in badminton has not been extensively examined. This study investigated the effects of high intensity intermittent badminton multi-shuttle (HIIBMS) feeding training on aerobic and anaerobic capacity, leg strength qualities and agility. Eighteen university college badminton players aged 20±1 (BW = 65.3±11kg; H =173.0±5.3cm) participated in this study. Based on the initial test results on aerobic and anaerobic capacity, leg reactive strength, and agility parameters, subjects were randomly selected and assigned into 2 groups (control group [CG], experimental group [EG]). Both groups had similar badminton training while additional training of HIIBMS feeding training was given to the EG for the duration of 4 weeks. The subjects were tested on VO2 max Test, Wingate Ergometer Test, Countermovement Vertical Jump, Drop Jump and Illinois Agility Test for the pre-test and post-test. Pre-test results showed insignificant differences between two groups implying that the they started equal in terms of 6 variables. Similarly, post-test revealed non-significant results for all the 6 variables. However, the comparison of pre-test and post-test mean scores showed significant improvements in VO_2max, mean power, leg reactive strength and agility except peak power and jump height in EG with CG showed no improvement in all parameters.

1 INTRODUCTION

Badminton is a popular recreational sport played by 200 million people world-wide. Physical demand of badminton is manifold requiring a mixture of technical and tactical skills, physiological fitness as well as psychological strength (Phomsoupha and Laffaye, 2015). Due to its high intensity intermittent nature (high intensity short efforts coupled with short rest interval; rapid shift of direction, jumps, lunges and powerful arm movements from a range of postural position), both the aerobic and anaerobic system is important for delivery during play and recovery (Andersen et al., 2007; Ooi et al., 2009; Jeyaraman and Kalidasan, 2012).

High intensity interval training (HIIT) has become an increasingly popular form of exercise due to its potentially large effects on exercise capacity and small time requirement (Foster et al., 2015). In fact, ACSM (2016) has accepted HIIT to be effective in improving sport performance through repeated bouts of high intensity effort followed by varied recovery interval. A short-term HIIT ranging from two weeks to six weeks could result in beneficial adaptations (Laursen et al., 2005; Burgomaster et al., 2006; Gibala & McGee, 2008; Little et al., 2011; Ziemann, Olek & Grzywacz, 2011; Gibala et al., 2012). Across those studies, reported induced adaptations through HIIT included enhanced carbohydrate metabolism, increase in lactate transport capacity, oxidative energy provision, and lactate metabolism as well as overall exercise capacity. Furthermore, although the impact of HIIT on neuromuscular adaptation had not been looked into extensively, recent studies were starting to emphasize on the acute neuromuscular response towards HIIT training (Buchheit and Laursen, 2013).

While HIIT is widely used in sports training (Ziemann, Olek and Grzywacz, 2011; Fernandez-Fernandez et al., 2012), multi-shuttle training (MST) is another popular training and has a specific approach towards badminton training session (Han,

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Li and Wang, 2011). It is a work with lots of shuttles fed randomly or with specific drills to the trainee. This MST method could solicit different types of training goals, including tactical, technical and physical (Han, Li and Wang, 2011; Hamedinia et al., 2013). To date, literature on the effectiveness of this training method is sparse. Thus, this study investigated the effects of high intensity intermittent multi-shuttle on aerobic and anaerobic capacity, reactive strength and agility among college badminton players.

2 METHODS

2.1 Participants

Eighteen male university college badminton players (age = 20±1 years; weight = 65.3±11kg; height =173.0±5.3cm) were recruited for this study. The sample size was considered adequate based on previous similar research studies which was 12 to 31 (Walklate et al., 2009 [n=12, CG=6, EG=6]; Ziemann et al., 2011 [n=21: CG=11, EG=10]; Fernandez et al., 2012 [n=32: CG=9, EG1=11, EG2=12]; Abdullah, 2014 [n=16: EG=8, CG=8]). All subjects were healthy and free of any chronic health conditions. The Physical Activity Readiness Questionnaire (PAR-Q) was administered to the subjects prior to participation to rule out contraindications to participation. The study was approved by the University College Ethics Committee. It conforms to the principles of the declaration of Helsinki of the World Medical Association where the subjects had been informed of the methods, procedures, benefits and potential risk before securing the written consent.

2.2 Research Design

This study applied the pre-test-intervention-post-test design. The subjects were divided into 2 groups (control and experimental) after pre-tests on aerobic, anaerobic (mean and peak power), reactive strength and agility parameters. The selection of subjects into the 2 groups were based on the Z-scores of the 6 tests and systematic counter balancing method. The 2 groups were then randomly assigned into the 2 conditions (CG, EG). For 4 weeks, both groups underwent normal badminton training routines while EG was provided with additional High Intensity Intermittent Badminton Multi-shuttle training (Figure 1).

2.3 Exercise Testing

All subjects underwent Bruce Protocol, Wingate Test, Countermovement Vertical Jump, Drop Jump and Illinois Agility Test. All tests were conducted in the laboratory and were based on the training schedule. To measure aerobic capacity, Treadmill (COSMED T200) and metabolic system (COSMED QUARK CPET) were used. The subjects warmed up at a walking speed for 8-10 minutes. After the warmup, the test started with subjects running at an incline/gradient of 10% and speed of 2.74 km/h. The incline and speed of the treadmill were increased every three minutes. The gradient was increased by 2% at every level. The subject ran to fatigue. To ensure subject has achieved maximum capacity, four conditions were monitored during the test: 1. Plateau in oxygen uptake (< 2ml.kg/ min or 3% with an increase in exercise intensity), 2. The respiratory ratio of 1.15 or above, 3. The final heart rate of within 12 bpm of the predicted age-related maximum, and 4. An RPE of 19 or 20 on the Borg Scale. Anaerobic capacity was measured using Braked Cycle Ergometer (883E Sprint Bike, Monark, Sweden). Participants started with a standardized 5-minute warm-up cycling at 25W. In the last seconds of the warm-up period, the subject increased their pedal rate to >100rpm with no resistance. After a 5-minute rest, the test began from a stationary starting position with the participant seated at the right pedal at approximately 45 degrees. A resistance pedalling equal to 0.075 kp per kg of body mass was applied at the onset of the Wingate Test (Ayalon et al., 1974). The subjects attempted to maximize their pedalling rate for the next 30 seconds under the prescribed resistance. Mean power and peak power generated from Monark anaerobic Test Software (Version 3.3.0.0) were used as an indicator of anaerobic capacity and was expressed in W/kg.

To measure leg reactive strength, Force plate (Bertec FP4060-10-4000, $\alpha = 0.978$ [pilot]) was used. Subjects dropped from a 30 cm plyometric box. The box was positioned directly behind a force plate. First, the force platform was set to zero without the participant on the platform. The participants were instructed to limit their ground contact time (GCT) between the drop from the box and the jump. To begin, participant stepped off the box and dropped onto the force plate landing with both feet and jump as high as possible. The jump height was calculated using the formula: Jump height = 9.81 * (flight time)^2 / 8. The best of three trials with GCT under 250 ms was used for analysis. The height in mm was divided by the time on the ground in milliseconds to determine the reactive strength index. To determine muscular power, Countermovement Vertical Jump Test was used (α = 0.89, Fah, 2012). Calculation of jump height was similar to reactive strength. Illinois Agility Test was used to measure agility (α = 0.965, Lim et al., 2012).

2.4 Multi-Shuttle Training

The multi-shuttle feeding training program lasted for 4 weeks. Each training session consisted of 3 sets of 10 repetitions workouts. In between each set, 1 min rest was given. Each repetition consisted of 15 seconds of high-intensity work followed by 30 seconds rest. In the 15-second workout, the experimental subjects hit 8 shuttles which were fed by the trainer. The feeding method was standardized with the trainer serving the shuttles with a badminton racket. The frequency of shuttle feeding was controlled by the metronome in Garmin Fenix 3 watch and the trainer kept feeding the shuttles to maintain high intensity. A heart rate monitor connected to Garmin Fenix 3 was used to monitor the heart rate response of the experimental subjects. The heart rate at the end of each set was recorded (Figure 2).

In order to ensure high intensity training, the heart rate (HR) of EG subjects were monitored by Garmin Fenix 3 to ensure high stress (HR ranging from 165bpm to 185bpm) as suggested by Ghosh (2008). Figure 2 illustrated the HR response from the EG subjects and it was in accordance to the suggestion by Gibala (2015) in which the targeted heart rate should be between 80-100% of maximal heart rate to stimulate related adaptations.

2.5 Statistical Analysis

The statistical software package "SPSS Statistics 23.0" (IBM) was used for statistical analysis. Mean value and standard deviation for the research parameters were calculated. T-tests were used for comparative analyses. The level of significance was set at $p < 0.05$.

3 RESULTS

The descriptive analyses were performed to provide pre-test, post-test and percentage improvement on the 6 variables that were measured using relevant tests. Results in Table 1 revealed that EG has the greatest improvement in VO_2max and Leg reactive strength respectively 10.08% (from 48.5ml/kg/min to 53.4ml/kg/min) and 41.53% (from 0.93 to 1.32) as compared to CG. While EG showed a slight improvement in mean power, vertical jump, and agility as compared to CG.

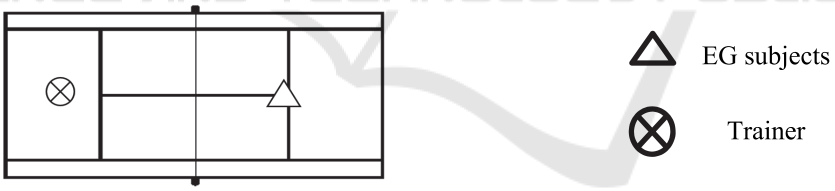

Figure 1: Multi-shuttle training.

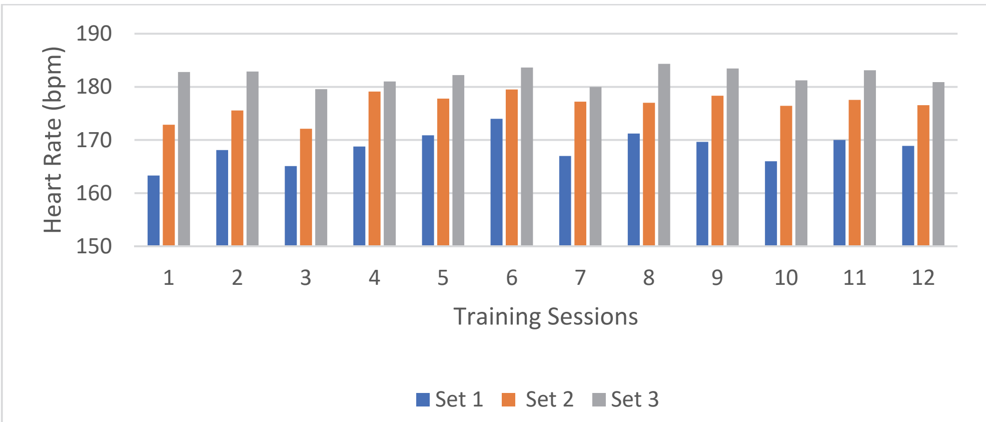

Figure 2: Heart Rate Response in each Training Session across 12 sessions for 4 weeks as measured by Garmin Fenix 3.

Table 1: Comparison of VO_2max, Mean Power, Peak Power, Jump Height, Reactive Leg Strength and Agility between the Experimental Group and Control Group. Data are means (±SD) and percentage improvement.

Variable	Experimental Group			Control Group		
	Pretest	Posttest	% of Improvement	Pretest	Posttest	% of Improvement
VO_2max (ml/kg/min)	48.5±8.4	53.4±6.7	10.08%	47.2±12.00	46.9±12.28	-0.73%
Mean Power (W/kg)	7.80±0.89	8.10±0.69	3.74%	7.66±7.0	7.85±0.79	2.38%
Peak Power (W/kg)	10.61±0.98	10.64±0.94	0.24%	10.65±0.86	10.74±0.90	0.86%
Jump Height (m)	0.39±0.08	0.41±0.07	5.76%	0.43±0.09	0.44±0.08	1.54%
Reactive Strength (RSI)	0.93±0.39	1.32±0.42	41.53%	1.06±0.14	1.11±0.40	4.82%
Agility (s)	17.66±0.76	17.09±0.69	3.23%	17.56±0.96	17.58±0.94	-0.11%

The inferential statistics comparing the pre-test mean scores of EG and CG (Table 2) showed that there were no significant differences in the pre-tests of all the six parameters of *VO_2max (0.263, p=0.796), Mean Power (0.37, p=0.716), Peak Power (-0.09, p=0.93), Jump Height (-1.221, p=0.24), Reactive Leg Strength (-0.677, p=0.508) and Agility (0.259, p=0.799)*. Similarly, in the post-test (Table 4), all the 6 parameters measures were not significantly different when EG and CG were compared; *VO_2max (1.398, p=0.181), Mean Power (0.713, p=0.486), Peak Power (-0.242, p=0.812), Jump Height (-0.899, p=0.382), Reactive Leg Strength (1.057, p=0.306) and Agility (-1.246, p=0.231).*However, an examination of pre-test and post-test performance for both groups (Table 3) revealed no significant differences in all the 6 parameters for CG but for EG, significant differences were found in *VO_2max, Mean power, Reactive Strength and Agility.*

4 DISCUSSIONS

The purpose of this study was to examine the effects of high intensity intermittent multi-shuttle badminton training on aerobic and anaerobic capacity, leg reactive strength and agility.

Even though HIIT has the potential to effect large exercise capacity within a short duration, the result of the post-test in this investigation showed no significant difference between EG and CG in all the 6 parameters (VO_2max, mean power, peak power, jump height, reactive leg strength, agility). Despite EG was provided with 4-week intervention (badminton multi-shuttle training), three 30 min sessions weekly, the result was not similar to that of Gillen and Gibala (2014). Gillen and Gibala (2014) reported that as little as three 10 min sessions weekly, with only 3 x 20s high intensity, could affect both muscle oxidative capacity and several markers of cardio-metabolic health even though this investigation employed 10 x 3 x 15s HIIT. The larger volume of training should be used as suggested by Selier et al. (2013) that individuals interested in enhanced outcomes (including competitive performance) should regularly do both a larger volume of training and higher intensity training.

4.1 Effect of High Intensity Intermittent Multi-Shuttle Feeding Training on Aerobic Capacity

In the present study, VO_2max marked a significant improvement of 10.08% (p=0.001) in EG while CG showed insignificant improvement of 0.73% (p=0.701). The significant improvement in EG's VO_2max was consistent with Sloth et al.'s (2013)'s finding in which the effects of a high-intensity interval training usually demonstrated increases of VO_2max by 4.2-13.4%. In addition, the increment of 4.9 ml/kg/min VO_2max corresponded to Ziemann, Olek and Grzywacz's (2011) finding that an improvement of 5.5 ml/kg/min VO_2max with a similar work-rest ratio interval training (1:2 work-rest ratio) on similar population (active college-aged men). Conversely, CG (-0.3 ml/kg/min) had a decrement in VO_2max. CG only had 3 regular sessions of match play each week with a training volume of fewer than 2 hours. In the view of the improved VO_2max, it might be explained by increased oxygen availability due to central adaptations or as a result of peripheral adaptations. However, central adaptations were less likely to happen through the present study's training protocol as effects on cardiac function would need peak-load (high intensity) durations of at least 2 or 3 minutes (Buchheit and Laursen, 2013) and also a training period of 8 weeks (Matsuo et al., 2014).

The high intensity intermittent multi-shuttle feeding training consisted of change of direction (COD) elements where the athletes moved from one corner to another corner quickly during the 15 seconds work phase. The inclusion of COD into HIIT had been proven to place high stress on the athletes regardless of the duration of the work interval (10s to 30s) (Dellal et al., 2010) and this has helped improved VO_2max of EG. In addition, Buchheit and Laursen (2013) highlighted that the peripheral as well as systemic cardiorespiratory system demand were higher during the COD type of HIIT, and this explained the significant improvement of VO_2max in EG. The effects of COD elements during sport skill training on VO_2max was reported by Karahan (2012).

4.2 Effect of High Intensity Intermittent Multi-Shuttle Feeding Training on Anaerobic Capacity

This study showed significant improvement of 3.74% in the mean power of EG and insignificant improvement in CG (2.38%). For peak power, both EG and CG showed insignificant improvement of 0.24% and 0.86% respectively. The percentage improvement of the mean power and peak power of this investigation was much less if the studies of Foster et al. (2015), and Ziemann, Olek and Grzywacz (2011) were compared. Ziemann, Olek and Grzywacz (2011) found 6-week HIIT program favorably influenced the aerobic and anaerobic performances of college subjects. On the other hand, the improvement in the anaerobic capacity through HIIT multi-shuttle feeding training in this study was similar to Walklate et al.'s (2009) finding in which the badminton players showed improvement in anaerobic parameters after involving in a 4-weeks badminton agility sprint training. Similarly, Karahan (2012) found improvement (10.7%) in mean power in a skill-based HIIT training. Laursen, Shing and Peake (2005) confirmed this observation, reporting that 4 weeks of HIIT increased anaerobic capacity as evaluated through accumulated oxygen deficit.

Table 2: A comparison of VO_2max, Mean power, Peak Power, Jump Height, Reactive Strength and Agility Pre Test Mean Scores between Experimental Group and Control Group.

		Mean	df	SD	t-value	Sig.
VO_2max	EG	48.5±8.4	16	8.4	0.263	0.796
	CG	47.22±12.0		12.0		
Mean Power	EG	7.80±0.89	16	0.89	0.37	0.716
	CG	7.66±0.70		0.7		
Peak Power	EG	10.61±0.98	16	0.98	-0.09	0.93
	CG	10.65±0.86		0.86		
Jump Height	EG	0.39±0.08	16	0.08	-1.221	0.24
	CG	0.43±0.09		0.09		
RSI	EG	0.93±0.39	16	0.39	-0.677	0.508
	CG	1.06±0.14		0.14		
Illinois Agility Test	EG	17.66±0.76	16	0.76	0.259	0.799
	CG	17.56±0.96		0.96		

*The mean difference is significant at the .05 levels

4.3 Effect of High Intensity Intermittent Multi-Shuttle Feeding Training on Reactive Leg Strength

Reactive strength is related to acceleration speed, change of direction speed, and even agility and is similar to the movements of EG subjects originating from the middle of the court to the corner where the shuttle was placed and returned to the middle of the court again. This might explain the result of this study where the reactive strength index demonstrated a significant improvement of 41.53% in EG and insignificant improvement of 4.82% in CG.

Conversely, this study showed insignificant improvement in jumping height (5.76%) for EG and CG (1.54%). This is supported by Vissing et al. (2008) that the improvement of agility related factor (leg strength) was relatively smaller in trained subjects who were familiarized with stretch-shortening cycle (SSC) exercise patterns. In this investigation, the EG subjects were trained badminton players.

The multi-shuttle training involved changes of direction (COD) movements. According to Gamble (2012) and Young, Dawson and Henry (2015), COD is highly correlated to reactive strength, thus explained the improvement in the reactive strength in EG. On the contrary, Born et al. (2016) in investigating the effect of multi-directional interval sprinting training on change of direction ability failed to support the result of this research.

4.4 Effect of High Intensity Intermittent Multi-Shuttle Feeding Training on Leg Power

This result of study showed insignificant improvement in leg power in EG (5.76%) and CG (1.54%). According to McBride, McCaulley and Cormie (2008), power involved in longer stretch-shortening cycle (SSC) compare to reactive strength. Since the multi-shuttle training was analogous to plyometric training which involved high force application and brief ground contact time (Gamble, 2012), the contribution of the slower SSC was less. Thus the transfer of the adaptation might be more specific towards reactive strength instead of leg power.

4.5 Effect of High Intensity Intermittent Multi-Shuttle Feeding Training on Agility

This investigation reported significant improvement of 3.23% of agility in EG and insignificant agility result for the CG (decrement of 11%). According to Rathore (2016) the significant result in EG, might be due to the fact that the court movements in the high intensity intermittent multi-shuttle feeding training were similar to plyometric training drills involving explosive stopping, starting, and changing direction movements. This might be due to the fact that the phenomenon of the stretch-shortening cycle (SSC) and is especially prevalent in an intermittent game like badminton. SSC actions

Table 3: A comparison of VO_2max, Mean power, Peak Power, Jump Height, Reactive Strength and Agility between Pre-Test and Post-Test Mean Scores in Experimental Group and Control Group.

Variable	Group	Pre-test	Post-test	df	t-value	Sig.
VO_2max	EG	48.5±8.4	53.4±6.7	8	-4.73	0.001*
	CG	47.2±12.00	46.9±12.28	8	0.40	0.701
Mean Power	EG	7.80±0.89	8.10±0.69	8	-2.41	0.042*
	CG	7.66±7.0	7.85±0.79	8	-1.93	0.089
Peak Power	EG	10.61±0.98	10.64±0.94	8	-0.11	0.915
	CG	10.65±0.86	10.74±0.90	8	-0.45	0.663
Jump Height	EG	0.39±0.08	0.41±0.07	8	-1.74	0.12
	CG	0.43±0.09	0.44±0.08	8	-0.63	0.545
Reactive Strength (RSI)	EG	0.93±0.39	1.32±0.42	8	-5.15	0.001*
	CG	1.06±0.14	1.11±0.40	8	-1.29	0.233
Agility	EG	17.66±0.76	17.09±0.69	8	6.79	0.000*
	CG	17.56±0.96	17.58±0.94	8	0.43	0.681

*The mean difference is significant at the .05 level exploit the myotatic reflex as well as the elastic qualities of tendons and muscle, and the resulting performance is independent of maximum strength in players.

As the EG subjects played on one side of the court and he was fed the shuttle from the opposite side by a coach. The subjects would rush to the backline and returned the shuttle executing required stroke from the back line, moving back to the center of the court. Due to the smaller size of half-court, explosive movements such as jumping, turning, initiation of movement, lateral movements and agility are extremely important than maximum speed (Kusuma, Raharjo and Taathadi, 2015). Similarly, Walklate et al. (2009) emphasized that the badminton specific repeated sprint conditioning intervention compromised a sequence of rehearsed movements covering the court and resulted in improvement of repeated sprint agility performance and anaerobic capacity. In addition, Lim et al. (2012) reported that the movements during the multi-shuttle training which included the change of direction movements involved performing the correct movements, performing accelerations and decelerations toward the shuttlecock, and performing sharp changes of direction or backpedaling. This is also supported by Holmberg (2009) in that agility is an acquired motor skill that can be trained. He stressed that badminton players could improve agility through technical training, pattern running and reactive training. Potteiger et al. (1999) concur that improvements in agility were a result of enhanced motor unit recruitment patterns. As a result of training, neural adaptations occurred in athletes. These adaptations consequently improved the coordination between CNS signal and proprioceptive feedback in athletes (Craig, 2004). In addition, this finding is also supported by Salonikidis and Zafeiridis (2008) which reported that their research subjects who underwent the tennis-specific drills training improved their speed and quickness of movement. This has indicated that the sports specific training in racket games contributed to the improvement in agility.

5 CONCLUSIONS

In conclusion, in this sample of college badminton players, our results suggest no particular advantage for high intensity multi-shuttle training model except some improvement for few variables for EG.

6 FUTURE RESEARCH DIRECTION

The research outcomes might be restricted by the duration of the experiment. Thus, a longer duration is suggested in future research. In addition, there is a possibility that differences in skill level among the badminton players might affect the adaptive response towards the training. Therefore, it is suggested that the training could be implemented on other badminton players with different skill levels starting from active young players to elite players to investigate its effectiveness on the above-mentioned performance variables.

Table 4: A comparison of VO_2max, Mean power, Peak Power, Jump Height, Reactive Strength and Agility Post Test Mean Scores between Experimental Group and Control Group.

		Mean	df	SD	t-value	Sig.
VO_2max	EG	53.4±6.7	16	6.7	1.398	0.181
	CG	46.9±12.3		12.3		
Mean Power	EG	8.10±0.69	16	0.69	0.713	0.486
	CG	7.85±0.79		0.79		
Peak Power	EG	10.64±0.94	16	0.94	-0.242	0.812
	CG	10.74±0.90		0.9		
Jump Height	EG	0.41±0.07	16	0.07	-0.899	0.382
	CG	0.44±0.08		0.08		
RSI	EG	1.32±0.42	16	0.42	1.057	0.306
	CG	1.11±0.40		0.4		
Illinois Agility Test	EG	17.09±0.69	16	0.69	-1.246	0.231
	CG	17.58±0.94		0.94		

*The mean difference is significant at the .05 level

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