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The relationship between upper and lower body power and strength and boxers' number of completed bouts

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Abstract

Background: Competitive boxers from southern region of Sweden, performed three different strength and power tests in the upper and lower body - body weight-relative standing rotational power (RSRP), countermovement jump (CMJ) and handgrip strength (HGS) - to evaluate correlations between number of completed bouts and the tests. **Aim**: The aim of this thesis was to investigate the linear correlation between number of completed bouts and three different tests – RSRP, CMJ and HGS in 16 male senior boxers. **Methods:** Male boxers, (n=16; 23±5 years; 76±11 kg bodyweight; 177±5 cm tall) from three different boxing competitive levels (C≤5 contests, B= 6-14 contests and A ≥15 contests) in the senior ranks (age 17-40) volunteered from several boxing clubs in Sweden. Participants performed the tests RSRP, CMJ and HGS and a correlation was made between the tests results and number of completed. **Results**: There was a positive moderate correlation (r_s=0.406) between CMJ and number of completed bouts and positive weak correlations (r_s=0.268, r_s=0.200) between RSRP and HGS and number of completed bouts. **Conclusions**: Weak and moderate correlations between the number of completed bouts in boxers and the strength and power tests in this study show that these tests do not necessary measure attributes needed in boxing. The three tests RSRP, CMJ and HGS can be relevant tests for evaluating upper and lower body strength and power, but their relevance should be reevaluated. There can be study designs with lower risk for bias as number of completed bouts does not seem to be the right variable for such correlation.

Abstrakt

Bakgrund: Tävlingsboxare från södra Sverige utförde tre olika styrke och kraft tester i över- och underkropp – kroppsvikts-relaterat stående rotations kraft (RSRP), countermovement jump (CMJ) och handgrepp styrka (HGS) – för att undersöka korrelationer mellan antal genomförda matcher och testerna. Till författarens vetande har inga studier tidigare genomförts på korrelationer mellan antalet genomförda matcher och styrke och kraft tester. **Syfte**: Syftet med denna studie var att undersöka den linjära korrelationen mellan antalet genomförda matcher och tre olika test – RSRP, CMJ och HGS hos 16 manliga senior boxare. **Metod:** Manliga boxare (n=16; 23±5 år; 76±11 kg kroppsvikt; 177±5 cm långa) från tre olika tävlingsgupper inom boxning (C≤5 matcher; B= 6-14 matcher och A ≥15 matcher) på senior nivå (ålder 17-40) från flera boxningsklubbar i södra Sverige deltog. Deltagare genomförde testerna RSRP, CMJ och HGS och en korrelation mellan testresultaten och antalet genomförda matcher gjordes. **Resultat:** Det fanns en positiv moderat korrelation (r_s=0,406) mellan CMJ och antalet genomförda matcher samt positiva svaga korrelationer (r_s=0,268, r_s=0,200) mellan RSRP och HGS och antalet genomförda matcher. **Konklusion**: Svaga och moderata korrelationer mellan antalet genomförda matcher och styrke och krafttesterna i denna studie visar att testerna inte nödvändigtvis mäter nödvändiga egenskaper för boxning. De tre testerna RSRP, CMJ och HGS kan vara relevanta tester för att utvärdera över- och underkroppsstyrka men deras relevans bör återundersökas. Det kan finnas studiedesigner med lägre risk för bias då antalet genomförda matcher inte verkar vara den avgörande variabeln för en sådan korrelation.

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Background

Boxing is one of the oldest sports of modern society and has been an Olympic sport since 1904 (IOC, 2015). The purpose in a boxing bout is to hit the opponent without getting hit. Most often the boxers are having the dominant hand distal to the opponent to be able to perform a punch with the greatest amount of power, the lead hand is tactically used to time the opponent. Depending on this boxers are divided into two stances, orthodox stance is most often kept by right handed boxers with the right foot in the back and the left foot in the front, southpaw stance is the opposite for left handed boxers with left foot in the back and right foot in the front. Boxers are divided into weight classes (men 46-91+kg, women 45-81+ kg) and further into three competitive levels depending on number of completed bouts: C, B and A (C<6 bouts, B=6-14 bouts and A>15 bouts) (SB, 2015). Boxers who have completed a higher number of bouts, based on the division, are considered to have a higher performance level. A boxing contest consists of three to four rounds depending on gender, men's bout in which consists of three three-minute rounds and women's bouts consists of four two-minute rounds in addition with one minute rest intervals. Boxing contests are won in one of three ways: scoring, knockout (KO) and technical knockout (TKO). In a scored bout boxers are given a score from three or five judges after each round, winner of the round is always given ten points and loser is given six to nine points depending on the winner's dominance. If a boxer is floored a limit of ten seconds is given to stand up and continue the bout. If boxer remains floored past the time limit the decision will be a KO, if boxer is floored three times during a round or judge and doctor decide to cancel the contest it is a TKO (AIBA, 2015).

Kinematics of boxing

Boxing is a challenging sport that requires high amounts of strength, agility, endurance, and coordination from the athlete (AIBA, 2011). Explosive strength, which is important for maximum punching force (MPF), is an ability to produce force with high velocity, raising the contraction rate and developing fast movements, thus explosive strength is a component related to MPF (Cheraghi, Alinejad, Arshi & Shirzad, 2014; Chaabéne et al., 2014). Explosive strength, or power, can be measured in watt (W) is the maximum amount of force developed over time across a distance in a specific period of time (Grimshaw, 2005). Walker and Turner (2009) describe agility as the ability to change direction quickly, combining power, strength and neuromuscular coordination without losing the balance. In boxing the opponents are constantly moving around each other, keeping a distance, all the time trying to time each other for attack and defense sequences (AIBA, 2011).

To be able to perform accurate and fluid movement in boxing, the movement of joints, muscles and senses must be synchronized which adds coordination as a skill for eminent boxers' (Chaabéne et al., 2014). In a punch, a rotation through the body starts from the feet and results in a higher MPF that can be developed adding momentum in transversal plane rather than only an arm extension in the sagittal plane (Cheragi et al., 2014). During the contact phase of a punch, stress is placed on hand and arm, this results in required work and strength to stabilize the involved joints. Therefore assessment of boxing performance should include testing for power in a rotational movement of the body and in the upper and lower limb separately (Loturco et al., 2015). Cheragi et al. (2014) found that the joints of the lower limbs provide speed and power production in a punch in boxers by a leg drive movement. In another study Loturco et al. (2015) performed numerous strength and power tests on elite amateur boxers and found strong correlations (r=0.80) between counter movement jump and a crossing punch from a self-selected stance, squat jump test also had strong correlation (r=0.78) with foregoing punch. The strong correlation from the jump tests shows that the optimal punch in boxing is dependent on the lower body limbs function and physiological capacity.

Physiology of boxing

Boxing challenges the athletes' body as a result of high intensity explosive movements along with endurance and requires great capacity from the energy systems. Ghosh, Goswami and Ahuja (1995) described boxing as 70-80% anaerobic and 20-30% aerobic. The high amount of anaerobic work in boxing, in which the athlete is working at high intensity close to maximal oxygen uptake (Vo2Max), results in high levels of lactate accumulation (McArdle, Katch & Katch, 2014). The high lactate levels lead to exhaustion and if a boxer is able to delay the time to exhaustion by achieving a higher tolerance to lactate, removal of lactate from the muscles and expand the use of oxygen. This way, the athlete gets greater ability to recover between the rounds of a bout (Ouergi, Hammouda, Chtourou, Zarrouk, Rebai & Chaouachi, 2013). All energy systems are active during exercise (figure 1), but differ in their dominance in energy production. The aerobic system dominates energy transfer during activities of low intensity, while the anaerobic system dominates in high intensity work when oxygen is absent (Baechle & Earl, 2008; McArdle et al., 2014).

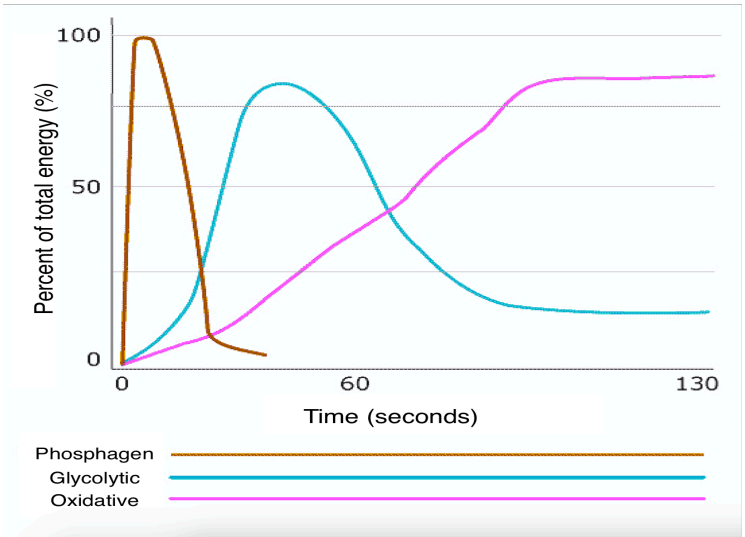

Figure 1. The three energy systems (immediate, anaerobic and aerobic) and their percent of capacity for work during maximum effort in relation to exercise duration. Based on figure by McArdle et al., (2014)

Adenosinetriphospate (ATP), which is the body's main energy containing molecule, is used for physiological processes as in muscle contraction. During anaerobic work, the energy demand is not covered by the rate of energy production through oxygen. The anaerobic system includes the short-term, glycolytic, and the immediate, phosphagen, energy systems. The immediate energy system is mainly dependent on stored ATP and phosphocreatine (PCr), where ATP is dephosphorylated to adenosine diphosphate (ADP), which in turn is rephosphorylated with the help of PCr. In the short-term energy system, energy is produced through a process called glycolysis where glucose is metabolized in the absence of oxygen to pyruvate, and lactate remains to be accumulated in the blood. During aerobic work, the long-term energy system is dominant, which in the presence of oxygen produces ATP from several macronutrients through metabolic processes that include the citric acid cycle and the electron transport chain. In explosive movements, like a boxing punch, the immediate and short-term energy systems will be dominant and power tests can therefore provide insight of the capacity in athletes anaerobic system (McArdle et al., 2014).

Since the lower limbs provide speed and power production in a punch in boxers by a leg drive movement, explosive strength in the lower limbs could be measured in a countermovement jump (CMJ). CMJ is a jump test, in which the subject performs a countermovement, which involves a stretching of the agonist muscle prior to the jump, and the jump involves a shortening of the same muscle. The course of the stretching and the shortening contributes to the power exerted during the test in a process called the stretch-shortening cycle (SSC) (McArdle et al., 2014). SSC is a process of the activation of the central nervous system through muscle spindles from an eccentric contraction (stretch) in a muscle. When an agonist muscle stretches in an eccentric motion, its muscle spindles

discharge impulses through the sensory neurons to the spinal cord which generates a stretch reflex so that the muscle contracts as a protective mechanism. Also, elastic energy is stored in the tendon for a short period of time and is termed as the amortization phase, which can be for additional use if an immediate concentric contraction follows in the antagonist muscle. If this temporary energy storage is not used for muscle work it will be lost in the form of heat and the additional spontaneous contraction initiated by the central nervous system would also be lost (McArdle et al., 2014). Bobbert and Casius (2005) show the practical use of the stretch-shortening cycle, explaining that athletes could jump 2-4 cm lower during a CMJ if the amortization phase is extended to avoid the use of the stretch-shortening cycle.

Tests for evaluating the performance level of boxers

Physical tests can be used to monitor athletes' physical performance level to track their development and assess their fitness levels for planning future training. To assess boxers fitness levels, the relevance of different tests to boxing needs to be evaluated. To assess the physiological characteristics that are mentioned above standing rotational power (SRP), counter movement jump (CMJ) and handgrip strength (HGS) could be used. In this section, these tests are described. Algotsson (2016) studied the validity and reliability of standing rotational power (SRP) tests using a 1080 Quantum cable machine by exploring its validity of SRP with a standing medicine ball throw (SMBT) which correlated strongly (r_s=0.80). Test-retest reliability for SRP was found excellent. The relationship between SRP and number of completed bouts has not been explored to present time, considering that rotational movement is a fundamental ability for boxers.

Research has been made on pubmed, searching for precious studies, which have investigated rotational power in boxing or boxing like sports as martial arts, tennis or baseball. No study was found for boxing but a similar rotational power test has been made previously by Miyaguchi and Demura (2012), whom investigated correlations between upper body strength from bench press and maximal velocity from a bat swing using a microwave-type speed-measuring instrument.

CMJ is a test for measuring jump height in a vertical jump, in which the flight time between take off and landing is measured and jump height is computed. Cheragi et al. (2014) found that lower limbs provide speed and power production in a punch in boxers and Nuzzo, McBride, Cormie and McCaulley (2008) showed that force development of lower limb power can be measured with counter movement jump (CMJ) test. Relationship between CMJ and number of completed bouts has to the author´s knowledge not been examined in any known present published investigation.

Maximal concentric grip strength in the upper body limbs can be measured with a hand grip strength (HGS) test using a hand dynanometer. A previous study by Guidetti, Musulin & Baldari (2002) investigated the relationship between HGS in the dominant hand and the boxers' international ranking according to their performance and found a strong correlation between boxing performance and HGS. Another study evaluated HGS in boxers' in relation to training phases and found that boxers performed higher during competiton periods than during general periods of training and therefore concluded that HGS test is suitable for assessment of boxers' performance (Garcia, Harasymowicz, Viramontes, Ordenes & Vazquez, 2010). To the author´s knowledge, no previous study has been published with data on tests investigating the relationship between HGS and number of completed bouts. Would a strong relationship between the mentioned tests and higher number of completed bouts be found, the tests would be useful for observing boxers' sport-specific performance level.

Aim

The aim of this thesis was to investigate the linear correlation between number of completed bouts in boxing and each of the three different tests – body weight-relative standing rotational power (RSRP), countermovement jump (CMJ) and handgrip strength (HGS) in 16 male senior boxers.

Research questions

- How strong is the linear correlation between number of completed bouts and test performance in RSRP?
- How strong is the linear correlation between number of completed bouts and test performance in CMJ?
- How strong is the linear correlation between number of completed bouts and test performance in HGS?
- Does the number of completed bouts describe the level of performance in Swedish male boxers?

Methods

Male boxers, (n=16, mean±SD, 23±5 years, 76±11 kg, 177±5 cm) at all competitive levels in the senior ranks (age 17-40) volunteered from several boxing clubs in Sweden from Halmstad (n=11) and Malmö (n=5). Testing was completed in a competition period between February and March 2017. Subjects would be actively competing at time of testing as inclusion criteria for participation in this

thesis. Height and weight were measured on each participant as height was necessary for the standardization of RSRP and the RSRP tests results were measured related to body weight of each subject. Exclusion criteria were illness or injury of any kind reported by participant before and at the testing day.

Study design

The study is an observational study containing cross-sectional data. Data were collected from subjects on one occasion, during a competition period. Correlations were made between subjects' number of completed bouts and the results in each performed test.

Material and testing procedures

Before testing, the subjects received a document (Appendix 2) containing guidelines for the upcoming tests and were informed of safety and details for each of the upcoming tests. Subjects choose to do practice runs before performing the tests (Tanner & Gore, 2013). Anthropometric measurements were taken before warm up and the tests were completed in the following order: CMJ, HGS and RSRP. An isometric strength pull test was made before the RSRP, which was included in another thesis.

Warm-Up

Warm-up was done according to the guidelines of Baechle and Earl (2008) and consisted of five-minutes of general warm-up on a lower body ergometer including four all out sprints of five-seconds during the last minute, a five-minute specific upper and lower limb warm-up and ended with five-minutes of dynamic stretching.

1080 Quantum

1080 Quantum is a modern cable machine system built for testing, research, rehabilitation and performance training and is a new instrument which 1080 motion AB started to develop in 2005. The system offers many functions such as measuring power, speed, acceleration and force, in both monitoring athletes and research. Its five-meter cable gives an excellent loading angle for free pattern of movement. Weight is adaptable between 0-50 kg concentric work and 0-75kg for eccentric work and movement speed of the cable is also adaptable to control the load and the time of the movement. The system offers several modes such as "Variable inertia", which works like a regular cable machine in the concentric phase but then rewinds the cable during the eccentric stage, which allows training in high velocity. "Normal weight" is another mode where the system will not pull the cable back in the eccentric stage, which allows the cable to slack (1080 motion AB, 2016). During body weight-relative

standing rotational power test (RSRP) a custom-made 120cm bar was attached to the machine (Algotsson, 2016).

Before RSRP, the bar was attached to the cable, Quantum 1080 mode was set to "no flying weight kg", concentric speed was set to 4m/s so that it would not limit the subject and eccentric speed was set to 0.8m/s for precaution so that the bar would not pull back in high velocity. A standardized stance was used, where the distance between the inner heels was marked at 0,33/body height, height of the cable was adjusted so the bar could be firmly placed below the subject's sternum. The standardized grip was holding the bar with dominant arm extended and firmly locking it against the body, below sternum, with the other arm. Subject was then instructed to stand in the specified stance, parallel with the feet, with the dominant hand pointing towards the machine (figure 2). To perform the RSRP, subjects were instructed to rotated with knees lightly bent in an upright position with maximum power and velocity until a full turn and the distal knee was passed. The bar had to rotate 180 degrees, without moving the feet, for a trial to be approved. Heel of the closest foot to Quantum 1080 was allowed to rise during the rotation but was not considered mandatory.

a) b)

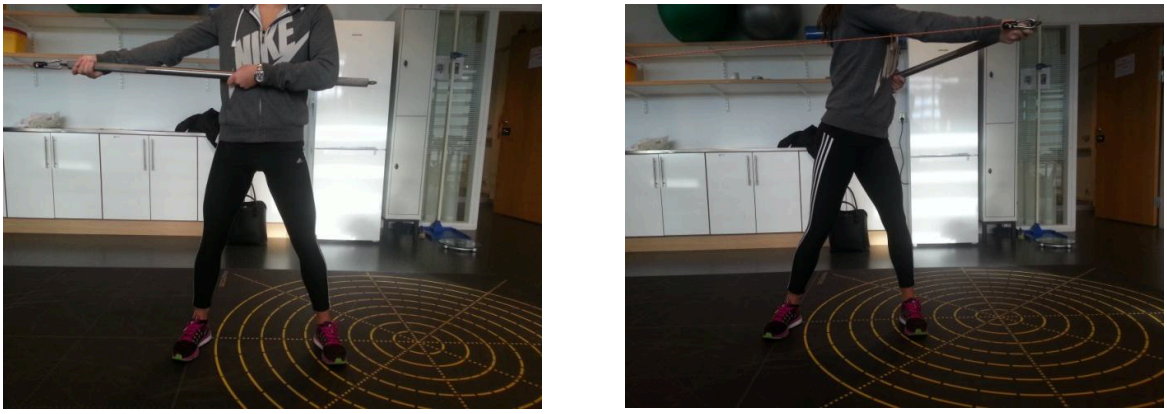

Figure 2. Starting position with knees slightly bent, bar firmly locked it against the body with humerus in one arm and dominant arm extended (a), and end of trial with a full turn till distal knee is passed (b). With permission from Algotsson, (2016).

First, 1RM was tested to determine the load for RSRP, which was 50% of 1RM. The 1RM test was performed starting at 60% of an estimated 1RM and the load was increased by 10% twice and 5% until the subject failed twice at a given load. The subjects rested for 4 minutes between attempts during the 1RM test and once the 1RM was determined, the subjects' rested for 5 minutes before performing the RSRP. The RSRP was performed three times with two-minute resting between attempts and the mean in peak power for the three attempts was recorded and the body weight-relative

mean in peak power (RSRP) was used for data analysis (Algotsson, 2016).

Countermovement jump

CMJ is a test for measuring jump height in a vertical jump, in which the flight time between take off and landing is measured and jump height is computed. CMJ is proclaimed to be valid and reliable test for measuring power in the lower limbs compared to alternative jump tests (Markovic, Dizdar, Jukic & Cardinale, 2004). CMJ was performed on an infrared-light (IR)-mat (IVAR, LN Sportkonsult Sweden 2016) with two sensors that create a field of IR-light, which records the time between take off and landing where participant breaks the IR-light (Markovic et al., 2004). In CMJ, the subjects were instructed to stand parallel, shoulder width between the feet in the zone of the IR-mat sensors with hands steadily placed on the hips during the whole procedure. Knees were flexed to a comfortable position followed by a maximum jump effort extending hips, knees and ankles. Subjects were required to land in the same position as takeoff with a double bounce to minimize stress on the knees. Subjects performed three jumps with one minute of resting between jumps and the mean of the three jumps was recorded for data analysis (Markovic et al., 2004).

Handgrip strength

Handgrip dynamometer is a spring-based instrument for testing HGS in the upper body limbs. The digital grip strength dynamometer (TKK Model 5401; Takei, Tokyo, Japan) can measure maximal concentric grip strength. The instrument is a reliable method for determining strength of the wrist and upper arm flexor muscles (Gerodimos, 2012; Cadenas-Sanchez et al., 2016). Subjects were instructed prior to the test procedure to stand straight with arms placed to the sides with the dynamometer placed in one palm and squeeze with maximum effort for two-three seconds without bending the arm. Both hands were tested starting with dominant hand and subjects were given one minute of rest between trials. Mean of the three trials in maximal isometric grip of dominant hand was recorded for data analysis with reference to previous research (Gerodimos, 2012).

Ethical and social considerations

Prior to the tests, subjects were given an informed consent (appendix 1) to read and sign, in which they obtained all information about the purpose and fulfillment of the thesis and concerning subjects' right to cancel their participation anytime without consequences. This thesis has according to the Swedish research council's guidelines taken into account that subjects' health is of priority and subjects' risk is not compromised for the thesis benefits. The subjects' personal identifiable information and results were maintained during the writing of this thesis and is kept on an USB memory in safe custody by the University of Halmstad.

The findings in this thesis may help boxers, boxing coaches and participants in other combat sports, such as kick boxing and thai boxing, to plan and evaluate boxing performance more systematically. For a social consideration the general population can benefit from knowledge about boxing, physical tests and the physiological characteristics of the sport of boxing. Regular exercise is confirmed to have numerous benefits on health such as preventing various diseases such as diabetes, obesity, fractures, depression, stroke, dementia and other cardiovascular, metabolic and psychological diseases. For that reason findings in this thesis may be valuable information for the general population (FYSS, 2011).

Statistical analyses

The statistical analysis was described with descriptive statistics and results were presented as mean ± standard deviation (SD). Data handled in this thesis were quantitative and the data was of the variable level ratio (Norman & Steiner, 2014). Shapiro-Wilks test of normality was done with significance level set to $p<0.05$ (Pallant, 2010). One variable was not of normal distribution, therefore Spearman´s correlation was used for data analysis to examine the correlation between number of completed bouts and RSRP, CMJ and HGS respectively. Correlation coefficients of 0,00-0,29, 0,30-0,49, 0,50-0,79 and 0,8-1,0 were considered weak, moderate, strong and very strong respectively (Pallant, 2010). Data was handled in SPSS program version 20.0 (IBM Corp, 2011).

Results

16 subjects, all men (23±5 years; 76±11 kg bodyweight ; 177±5 cm tall), completed the three tests RSRP, CMJ and HGS. The majority of the subjects were A and B class boxers n=14 (88%), figure 3 shows the distribution between competitive level (C, B and A) of subjects.

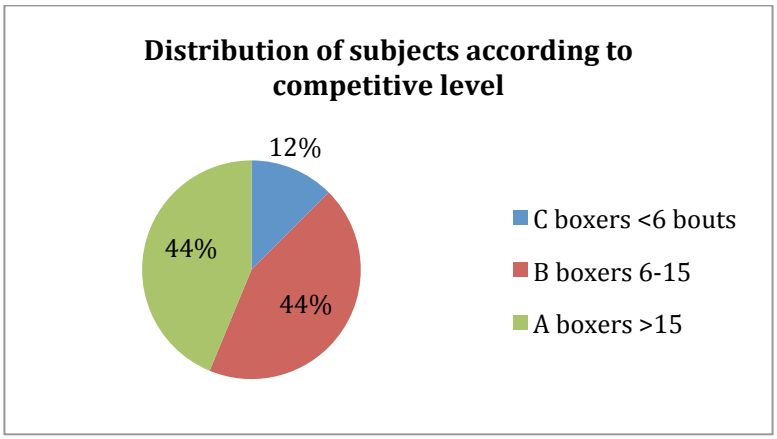

Figure 3: Distribution of subjects according to competitive levels (C, B and A; n=16).

The groups variables of number of completed bouts, RSRP (W/kg), CMJ (cm) and HGS (kg) are presented in table 1 as mean and standard deviation for all variables.

Table 1 Mean and standard deviation for number of completed bouts, RSRP, CMJ and HGS (n=16).

Variable	Mean	Standard deviation (SD)
Number of completed bouts	17	11
RSRP (W/kg)	13	3
CMJ (cm)	36	4
HGS (kg)	53	9

RSRP = Standing rotational peak power relative to body weight; CMJ = Counter movement jump; HGS = Handgrip strength.

The correlations are presented in table 2 as Spearman coefficient of correlation, level of significance and coefficient of determination. The highest correlation with number of completed bouts was CMJ (r_s=0.406) and is presented in figure 4. Spearman correlation (r_s) showed that there was a weak positive correlation (r_s=0.268) between RSRP and number of completed bouts, moderate positive correlation (r_s=0.406) between CMJ and number of completed bouts, and weak positive correlation (r_s=0.200) between HGS and number of completed bouts. The levels of significance show a high risk that the correlation may have appeared by chance for RSRP, CMJ and HGS (p=0.315; p=0.118; p=0.457 respectively).

Table 2 Results of the data analysis of the Spearman coefficient correlation between number of completed bouts and the results from the tests: RSRP, CMJ and HGS (n=16).

Variable	Number of completed bouts
RSRP	r_s=0.268 (p=0.315 r^2=0.072)
CMJ	r_s=0.406 (p=0.118 r^2=0.165)
HGS	r_s=0.200 (p=0.457 r^2=0.040)

RSRP = Standing rotational peak power mean relative to body weight; CMJ = Counter movement jump mean; HGS = Handgrip strength mean.

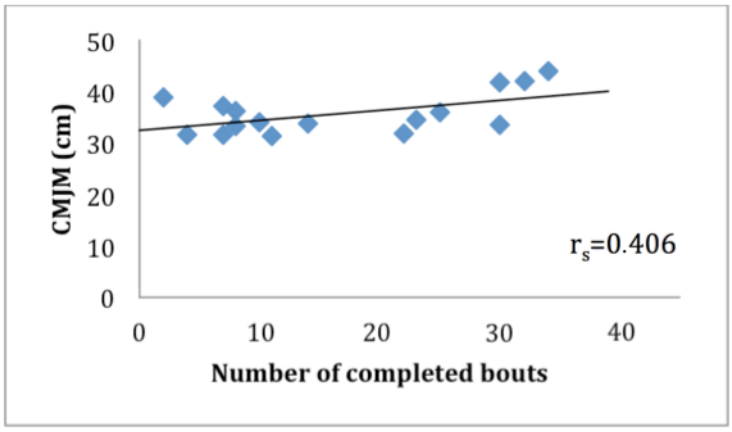

Figure 4: Spearman correlation between CMJ and number of completed bouts (r_s=0.406; n=16).

Discussion

Discussions on results

The present thesis evaluated the relationship between number of completed bouts in boxing and strength and power tests in competitive boxers of Sweden. Small to moderate correlations between number of completed bouts and RSRP, CMJ and HGS shows either that number of completed bouts does not represent performance level in boxers, that the group may be deceptive in the case of representing competitive boxers or that these test does not predict boxing performance level. A weak correlation (r_s=0.268) was found between RSRP and number of completed bouts. In contrast to previous research (Miyaguchi & Demura, 2012) found stronger correlation (r=0.62) between upper body strength and bat swing speed in national competitive baseball players.

In the present thesis a moderate correlation in the CMJ (r_s=0.406) was found. In conjuction Loturco et al. (2015) found stronger correlations (r=0.80) between counter movement jump and a crossing punch from a self-selected stance in elite amateur boxers

The results from this study show that there was a weak correlation between number of completed bouts and HGS (r_s=0.200). This is in contrast to previous research (Guidetti et al., 2002) which found a much stronger correlation (r=0.87) between international ranking of middleweight boxers and HGS, and that their performance in HGS differed according to training period.

Boxers at a higher competitive level, and thus boxers with a higher number of completed bouts, often exercise more and on a higher level of intensity and volume than boxers at lower competitive level. This means their physical condition should give them the opportunity to perform better at strength and power tests (Baechle & Earl, 2008). As mentioned earlier, a classification system is used in Sweden, which divides boxers into three competitive levels depending on number of completed bouts: C, B and A (C<6 bouts, B=6-14 bouts and A>15 bouts) (SB, 2015). The boxers included in this study were actively competing at different competitive levels with 7 subjects at A-level, 7 at B-level and 2 at C-level. According to the results of this study, that contradict earlier research, the number of completed bouts may not represent upper and lower body limb strength in boxers.

Also, when it comes to strength and power tests, the motivation level of the subjects to perform well could be vital for the results as the willingness to perform is a psychological aspect which determines the amount of effort subjects puts in the trials. The subjects in this study got the opportunity to make trials of each tests prior to the tests, which should have raised their level of self-confidence, which would influence their level of motivation. During testing the subjects were encouraged to perform at their best by verbal encouragement during the trials and positive feedback from the test leaders after the trials. These aspects resulted in the group having a high level of motivation to perform well (Weinberg and Gould, 1995).

Method discussions

Number of completed bouts

The number of completed bouts was correlated to the test results in RSRP, CMJ and HGS in this thesis, but using number of completed bouts as a measure of performance level could be erroneous. For example, some of the subjects included may have had previous experience in physical exercise or combat sports, which would affect their results since they may have had a low number of completed bouts but still performed well on the power and strength tests. On the other hand some of the subjects may have had completed a high number of bouts over a long period of time and have not sustained their physical level to perform well in these tests. For example, young newcomers that only completed

a couple bouts and won all of them would probably perform better with higher results.

Guidetti et al., (2002) found strong correlation (r=0.87) between the international ranking of middleweight boxers and handgrip strength. This shows that in this thesis, the subjects did not represent boxers as a population the way boxers did in the study of Guidetti et al., (2002). This also shows that the number of completed bouts may not explain strength and power in boxing as an international ranking would explain boxing performance. However, this thesis was limited to the boxers that were available in the southern region of Sweden.

The type of boxing style in boxers can also affect the results, as an offensive boxer may have developed more strength and power than a defensive boxer which may have focused on endurance and durability in his boxing. This is confirmed by AIBA (2011) that describes that a boxers training should be planned due to their specific style of boxing, focusing on strengths and weaknesses, and with respect to their body type. This kind of tactical training can result in the boxers optimizing their performance according to their boxing style. The differences between boxing styles could be investigated with an anaerobic test like an upper body Wingate test, which would show if the boxer is more explosively or anaerobically trained (McArdle et al. 2014).

Material and testing procedures

The choice of the tests was made based on previous research that have either showed the tests' relationship to boxing or a relationship to the physical and physiological characteristics discussed above in the physiology section. The test procedures in this thesis were completed according to valid and reliable methods from previous research, which means that the application of the tests procedures should not have affected the tests results (Algotsson, 2016; Markovic et al., 2004; Andre et al., 2012; Gerodimos, 2012; Gordon, Moir, Davis, Witmer, & Cummings, 2009; Guidetti et al., 2002). However, the testing took place in two different but similar laboratories, in Halmstad and in Malmö, where the testing environments were also similar and with the same test leaders. The same equipment was used for HGS and CMJ, but a different Quantum 1080 was used, which implies that the results may have been affected for RSRP.

Alternative methods

An alternative way to evaluate different tests' suitability to boxing could be to compare a group of competitive boxers with a control group of non-boxers. This alternative method could, more systematically, show if the RSRP, CMJ and HGS tests are relevant tests for evaluating boxers'

performance. To test the same group of boxers during an off season and a competitive season could also give results with lower risk for bias, as the boxers train with different intensity and volumes during these periods of time.

For further studies on boxers and non-competitive boxers, a research question could be: Is there a significant difference between test group and control group in RSRP, CMJ and HGS? In the future these test may be relevant methods for evaluating boxers performance level. Most interesting would be if a national team of boxers would perform these tests, as they represent a high ranking of competitive boxers, and thus a homogenous group. On this topic, a research question on nationally ranked boxers could be: How strong is the linear correlation between the national ranking of a group of boxers and their performance in RSRP, CMJ and HGS?

Conclusion

Weak and moderate correlations between the number of completed bouts in boxers and the strength and power tests in this study show that these tests do not necessary measure attributes needed in boxing. The three tests RSRP, CMJ and HGS can be relevant tests for evaluating upper and lower body strength and power, but their relevance should be reevaluated. There may be a stronger relationship between the tests and boxing competitive level but the number of completed bouts may not be the right variable for the correlation.

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Appendix 1 – Informed consent (Swedish)

Vi är två studenter på Högskolan i Halmstad som läser kandidatprogrammet inom Biomedicin med inriktning fysisk träning. Just nu skriver vi våra kandidatuppsatser där vi utvärderar samband mellan styrke- och uthållighetstester och boxares nivå. Det är två vetenskapliga studier som sammanlänkar varandra. Bakgrund till studierna är att det idag inte finns kända vetenskapliga studier som påvisar samband mellan de valda, kända testerna och respektive tävlingsnivå inom boxning. Genom att delataga i vårt examensarbete kan du få ett tillfälle att testa din fysiska kapacitet och få tillgång till dina resultat medans du hjälper vår sport att utvecklas.

Deltagande innebär ett testtillfälle där de fyra testerna kommer att genomföras. Testtillfället börjar med styrke- och power-tester; ett *hopptest* med hjälp av en IR-matta för explosivitet i underkroppen, ett *isometriskt styrketest* för maximal styrka i underkropp, *handgreppsstyrka* i båda händerna med hjälp av en handdynamometer för styrka i hand, arm och axel samt ett *stående rotationstest* för *maximal styrka* och *explosivitet i rotation*, vilka genomförs i maskinen 1080 Quantum.

Efter styrke- och power-testerna följer en vila på 20 minuter uppföljd av ett max test, *Wingate anaerobt test*, som varar 30 sekunder och genomförs i en armcykel för att ge värden på anaerob kapacitet i överkroppen. Samtliga tester är maxtester men är måttligt ansträngande att genomföra för en träningsvan person. Vid testtillfället kommer även antal genomförda matcher att noteras för att en jämförelse mellan boxares nivå och resultat från fystesterna kan genomföras och längd och vikt kommer att mätas hos deltagare.

Testerna kommer att genomföras *noggrant* med ständigt närvarande testledare och säkerhet för testdeltagare prioriteras för att minimera skaderisken. Testerna kommer äga rum i N-huset på Högskolan i Halmstad. Testerna beräknas att sammanlagt att ta ca 1-2 timmar att utföra.

För att delta i studien ska du vara på seniornivå (mellan 18-40år) samt aktivt tävlande inom boxning. Vid testtillfället ska du vara fri från skada eller sjukdom i kroppen för att deltaga och om sjukdom eller skada uppstår innan testtillfället bör du säga till testledare.

Deltagande i studien är helt frivilligt och du har befogenhet att när som helst under studiens gång avbryta din medverkan utan att behöva förklara varför. Samtliga uppgifter som samlas in under studien förvaras konfidentiellt. Dina personuppgifter och ditt deltagande framkommer inte i projektet. Studiens resultat såväl som dina egna resultat kommer du som deltagare att få ta del av.

Jag godkänner att information om mig och mina testresultat hanteras av testledare.

Jag bekräftar att jag valfritt deltar i studien och har kännedom om att jag kan hoppa av studien när jag vill utan att frågor ställs.

Jag har tagit del av information om vad jag deltar i studien med och vilka risker som finns.

Jag har tagit del av information om vad studiens syfte är och nyttan av dess genomförande.

Jag har tagit del av ovannämnd information och ger mitt samtycke att delta i studien.

_____

Namnförtydligande

_____

Underskrift, Ort och Datum

Är du under 18 år krävs målsmans namnteckning.

_____

Målsmans namnförtydligande

_____

Målsmans underskrift, Ort och Datum

För frågor eller mer information om studien, testerna eller resultat är du välkommen att kontakta någon av nedanstående via telefon eller mejl:

Mohammed Khudair, Testledare
xxxxxxxxx, mo.frss@gmail.com
Mikael Dabrowski, Testledare
xxxxxxxxx Powski90@gmail.com
Eva Strandell, Handledare
Eva.strandell@hh.se

Appendix 2 – Information (Swedish)

Riktlinjer inför tester

- Genomför testerna om du känner dig frisk och är fri från skador. Meddela testledare om du inte kan genomföra testerna.
- Undvik hårdare träning 48 timmar innan testet.
- Välj lättare träning om du ska träna dagen för testerna.
- Undvik att äta två timmar innan testerna.
- Avstå från koffeinhaltiga livsmedel, läkemedel och kosttillskott.
- Avstå från att röka eller snusa timmarna innan testet.
- Var ombytt till lättare träningskläder och träningsskor inför testerna och ta med dig en vattenflaska.
- Du får göra uppvärmning på plats, dvs du behöver inte värma upp innan testerna.

Under tester

Testerna genomförs i labbet på högskolan i Halmstad, byggnad N, Linjegatan 10. Beräkna ca 90 minuter för genomförandet av testerna och kom i god tid.

Testerna består av mätning av längd, armspann och vikt som följs upp av styrke- och explosivitetstester och avslutas med ett anaerobt maxtest för överkroppen.

Handstyrka

Här mäts handstyrka med hjälp av en handdynamometer som ger er ett värde på styrka i hand, arm och delvis axel.

Här ska du stå upprätt med händerna vid sidan med dynamometern vid sidan. Sedan trycker du så hårt du kan utan att böja på armen. Testet genomförs tre gånger på varje hand.

Countermovement jump

I detta hopptest mäts explosivitet i benen med hjälp av en IR-matta som mäter tiden i luften och räknar om det till hopphöjd.

Här ska du stå på IR-mattan med benen parallella och händerna på höfterna. Vid klartecken från

testledaren böjer du på benen till en bekväm position och hoppar så högt du kan. Händerna ska ligga kvar på höfterna genom hoppet. Vid landning genomför du en dubbelstuds för att landningen ska vara skonsam för knäna. Testet genomförs tre gånger.

Stående rotationstest

I detta test mäts explosivitet i en stående rotation som liknar ett rakt bakre slag och mätningen görs i Quantum 1080.

Här ska du ställa dig med den självvalda sidan mot maskinen. Du håller i en pinne som är kopplad till maskinen och denna ska ligga framför dig, strax under revbenen och hållas kvar med ena armen medan andra armen är rak och håller änden på pinnen. Fötterna är parallella och avståndet mellan dem är en tredje del av din längd, vilket kommer att räknas ut av testledare i förväg. Vid signal roterar du så kraftfullt och snabbt som möjligt. Testet genomförs tre gånger.

Wingate anaerobt test för överkroppen

I detta mäts din anaeroba kapacitet och power, förmågan att bibehålla hög intensitet och fortfarande skapa kraft. Testet genomförs på en armcykel, för att imitera boxningsrörelsen, mot ett motstånd som motsvarar 5% av din kroppsvikt som kommer att beräknas och förberedas av testledare i förväg.

Här ska du cykla med händerna så snabbt du kan i tre sekunder för att komma upp i maxhastighet innan motståndet läggs på. När motståndet läggs på ska du cykla så snabbt du kan i 30 sekunder för att försöka bibehålla så hög intensitet som möjligt. Testet genomförs en gång.

Efter tester

Efter testerna kommer du att kunna ta del av dina testresultat. Resultat att sammanfattas för att söka en koppling av dessa tester till boxning, vilket innebär att de kan användas för att testa boxares fysiska nivå.

Appendix 3 – Equipment

Adhesive tape

Custom-made bar owned by Halmstad University

Quantum 1080, 1080 motion AB

IVAR, LN Sportkonsult Sweden

Seca 213 portable stadiometer ,Seca Deutschland, Germany

Tape measure

TKK Model 5401; Takei, Tokyo, Japan

Vågblock VB2-200-50 VETEK, Vaddö, Sweden

Computer with SPSS 20.0

Mikael is a 26 year old Professional Kiteboarder and Taekwon-do black belt from Kungsbacka, Sweden.

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